# AGRICULTURE
THROUGH THE LABORATORY
AND SCHOOL GARDEN

JACKSON & DAUGHERTY

E. B. Babcock.

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HYBRID CARNATION.

A. SCOTT, FEMALE PARENT. C. HYBRID. B McGOWAN, MALE PARENT.

# AGRICULTURE

## Through the Laboratory and School Garden.

A MANUAL AND TEXT-BOOK OF ELEMENTARY AGRICULTURE FOR SCHOOLS.

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"Give men their gold, and knaves their power,
Let fortune's bubbles rise and fall,
Who plows a field, or trains a flower,
Or plants a tree is more than all;

For he, who blesses, most is blessed,
And God and man will own his worth
Who seeks to leave as his bequest
An added beauty to the earth."

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# INTRODUCTION.

FROM the growth and drift of public sentiment it is evident that education in Agriculture will soon be offered in all good elementary schools of our country. This, from the nature of the case, seems unavoidable, because such instruction is essential both for utility and for culture. It is an essential utility, because it is the only means of furnishing adequate conceptions of the one fundamental occupation of mankind upon which all other occupations depend.

For the masses it is an essential basis of true culture and refinement, as illustrated in its earliest fruitage, which is the adornment of homes through improved lawns, shade-trees, walks, driveways, gardens, flowers, etc., thereby opening the avenues to consciousness and revealing in the most pleasing way the beauty world all around us.

This volume is unique. It is not the product of its authors' imaginations. No one designed it to exploit a theory or a person. It is an outline of work done—done by ordinary people under ordinary conditions.

The Agricultural Laboratory and the School Garden of the Kirksville Normal School have

grown from very small beginnings. They are now the objects of keen interest in many parts of the United States. Their purpose at all times has been to prepare teachers to give practical and definite agricultural instruction in public schools of all kinds.

JOHN R. KIRK.

President Kirk was one of the pioneers in introducing Agriculture into the Normal School.—AUTHORS.

# PREFACE.

THE preparation of this book was undertaken, primarily, that the classes in Agriculture of the State Normal School of Kirksville, Missouri, might have in one book the directions for all laboratory experiments and exercises, and such information as would enable them to understand the results of these experiments.

We believe that the book will meet the needs of most schools where Agriculture is taught or should be taught.

It has been deemed necessary to embody in the text such facts and principles of Geology and Botany as are absolutely essential to the understanding of agricultural principles and processes.

The work is intended to cover one year's time, but any part of it may be omitted if the necessary materials cannot be obtained. The time to be spent upon each phase of the work must be determined by the class, the materials accessible, and the teacher.

It is neither pedagogical nor scientific to tell a student what he can find out for himself. It takes away both the incentive and the necessity for experimental work to foretell the result.

Our aim has been to present actual experimental work in every phase of the subject possible, and to state the directions for such work so that the student can perform it independently of the teacher, and to state them in such a way that the results will not be suggested by these directions. One must perform the experiment to ascertain the result.

Any energetic teacher can, by carefully going over the work in advance, working out the experiments himself and reading the references, be able to do creditable class work if he is willing to "dig," but it is useless for any one else to undertake to be an agriculturist or to teach agriculture.

Every available source has been drawn upon for the material used in this book, but the plan of presenting it is original, as well as most of the experiments and exercises, and many practical ideas gained from experience in teaching.

We wish to express our grateful appreciation to all those who have so kindly helped us by reviewing the manuscript or by loaning us illustrations.

The following persons from the United States Department of Agriculture at Washington have been very helpful: The manuscript was examined by B. T. Galloway, Chief of the Division of Plant Industry; W. J. Spillman, Agrostologist; A. F. Woods, Pathologist and Physiologist;

and M. B. Waite, Assistant Pathologist. The chapters on "Propagation," "Improvement," and "Pruning" were read by L. C. Corbett, Horticulturist, and the one on "Enemies of Plants" by the Entomologist, Mr. Wilcox. "Ornamentation of School and Home Grounds" was read by Mr. Crosby. The chapter on "Enemies of Plants" was also read by H. Garman, State Entomologist of Kentucky. The first half of the book was examined also by Professor Mumford, Acting Director of Missouri Experiment Station, and by W. T. Carrington, State Superintendent of Schools. The second half was examined by J. C. Whitten, Horticulturist, Missouri Experiment Station. The first chapter was criticised by C. F. Marbut, Assistant Professor of Geology, University of Missouri.

The second half of the manuscript was examined by President John R. Kirk and Dr. L. S. Daugherty, of the State Normal School, Kirksville, Missouri. The entire manuscript was submitted to H. J. Waters, Superintendent of Agriculture, World's Fair, St. Louis, Missouri.

We are indebted to the following persons and Experiment Stations for illustrations: Experiment Stations of Minnesota, West Virginia, Rhode Island, New Hampshire, Kansas, Missouri, Ithaca, New York, New Jersey, Texas, and that of Hampton Institute (Va.); to the

United States Department of Agriculture; the United States Geological Survey; *Ladies' Home Journal;* Orange Judd Co.; Waugh's "Landscape Gardening"; D. C. Heath & Co.; Leggett & Brother; The Deming Co., and others mentioned with the figures.

THE AUTHORS.

KIRKSVILLE, MO., 1905.

# CONTENTS.

# ILLUSTRATIONS.

# AGRICULTURE
## THROUGH THE LABORATORY AND SCHOOL GARDEN.

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## OUTLINE OF CHAPTER I.

### NATURE AND FORMATION OF SOILS.

### *A.*—SOURCES OF ENERGY.

**I. The Earth's Energy.**

**II. The Sun's Energy.**

### *B.*—FACTORS OF SOIL FORMATION.

**I. The Atmosphere.**

1. *It Regulates the Temperature.*
2. *Movements of the Atmosphere.*
3. *Chemical Action.* EXPERIMENT 1.
4. *Alternations of Heat and Cold.*

**II. Water.**

1. *Chemical action.*
2. *Mechanical Action. Disintegrating, transporting, assorting.* EXPERIMENT 2.
    (1) RIVERS. EXPERIMENT 3.
    (2) UNDERGROUND STREAMS.
    (3) LANDSLIDES.
    (4) LAKES.
    (5) THE OCEAN.
    (6) FROST.

(7) ICE.
(8) SNOWSLIDES.
(9) GLACIERS.
(10) ICEBERGS.
3. *Field Exercise No.* 1.

## III. Organic Life.

1. *Plant Life.*
    (1) MECHANICAL OR PHYSICAL EFFECTS. 5
    (2) CHEMICAL EFFECTS. acids- Bacteria.
    (3) VEGETABLE ACCUMULATIONS. 3
2. *Animal Life.*
    (1) DISINTEGRATION.
    (2) ANIMAL ACCUMULATIONS.
        Calcareous Deposits.
        Siliceous Deposits.
        Phosphatic Deposits.
3. *Environmental Changes.*
4. *Field Exercise No.* 2.

# CHAPTER I.

## NATURE AND FORMATION OF SOILS.

Soil is derived, primarily, from rock * in the broadest sense of the term. The cycle of tearing down in one place and building up in another has been constantly going on for ages, and is still going on to-day. It is to this cycle of changes, discussed in the following pages, that we owe the presence of the loose surface material of the earth (some places a few hundred feet in depth, and in some places entirely wanting) which *makes it possible for plants* and animals to live, and which loose material forms the basis of all soil.

### *A.*—SOURCES OF ENERGY.

The matter which constitutes the earth and atmosphere, though it cannot be destroyed, is constantly changing its form, under the action of existing forces. The *sources* of all these forces, or of our supply of energy, are *the earth and the sun.*

**I. The Earth's Energy.**

The earth's energy is from within, and some of its manifestations are the upheavals and disruptions of the crust, and, greatest of all, the

* "Any substance constituting a portion of the earth's crust . . . is called a rock."—Leconte's *Compend of Geology*, p. 178.

force of gravity, without which nothing could remain upon the surface of the earth, owing to the centrifugal force caused by the rotation of the earth.

Other forms of energy are the molecular‡ forces of cohesion‡ and adhesion,‡ and the atomic force of chemical affinity, all of which exist within the substances themselves, and act at insensible distances.

**II. The Sun's Energy.**

The great source from which we derive, either directly or indirectly, most of our energy is the sun. "The circulation of winds and waters, the changes of temperature, and the activities of living beings all depend upon the sun's energy,"* without which there could be upon the surface of the earth no motion and no life.

The sun's energy comes to us, it is believed, by means of waves in the ether of space. Some of these waves produce the various colors, or are what we might call light waves; others are not perceptible to the human eye, but are heat waves; still others are especially productive of chemical changes, as is manifested in photography.

When the sunshine falls upon the soil a portion of it is absorbed, and the molecular motion

‡ Terms thus marked (double dagger) throughout the book are found in the Glossary.

* Scott's *Geology*, p. 29.

within the soil is increased, producing a certain amount of heat. This heat, when transmitted to the air, causes it to expand and thus become lighter, when the cooler and heavier air rushes in from the sides, forces it upward, and wind results; if transmitted to the water, the increase Wind
of the molecular motion of the water overcomes the force of cohesion, and evaporation ensues.

As the vapor rises it gradually becomes cooled and condensed, and clouds composed of minute Clou
particles of water* are formed; these minute particles of water, after further cooling and condensing, are united by cohesion into drops, and are drawn back to the earth by the force of gravity, in the form of rain, snow, or hail. These few examples may serve to show how the Coa
sun's energy is transformed into a multitude of activities.

## *B.*—FACTORS OF SOIL FORMATION.

### I. The Atmosphere.

1. *It Regulates the Temperature.*—On winter nights the lower layer of air—especially if laden 2 Wa
with dust and moisture—acts as a blanket in checking radiation of heat from the earth's surface. But, in the intense heat of summer, this lower layer of air would, through radiation

* "Clouds formed at temperature above 32° consist of minute spherical drops of water 1-4000 to 1-1000 of an inch in diameter; those formed below 32° consist of minute ice spicules which increase in size and become snow."—Davis' *Meteorology*, pp. 159, 160.

of heat from the earth, become unbearable for all living beings were it not for its currents, caused by the expansion of the heated air which renders it lighter and causes it to rise, while the cooler air above, being heavier, descends by the force of gravity.*

ause 2. *Movements of the Atmosphere.*—It is to these movements—due, primarily, to the coun-
sults teraction of the sun's energy by the force of
1- gravity—that we owe the formation of clouds and the condensation of their moisture; the dis-
2- tribution of gases to act upon the rock surface, or to be consumed by living beings; the circu-
3- lation of air in the soil, so essential to plant life;
4- the transportation of plant food and of seeds;
5- and the maintenance of the relative composition of the whole atmosphere. It is through these movements that the air travels to the sea and back again, bringing moisture for the thirsty life.

*The winds* play an important part in the formation of soil: (*a*) in the disintegration of
rosion rocks, by pelting them with sand or rain, thus mechanically wearing them away by friction; (*b*) by keeping them bare, so that they are exposed to other atmospheric forces; (*c*) by stir-
stribution

* "Professor Langley, after a long and careful experiment at the base and summit of Mount Whitney, California, concludes that had our earth no atmosphere its surface temperature under the equator at noon would be 328° F."—*The Soil*, King, p. 13.

ring up the ocean into waves and billows, which beat upon the rocks, carrying with them sand and pebbles, which grind each other into powder.

On the sandy beach of the ocean and of the great lakes, and in the great sandy plains, or wherever the sand is loose and unprotected by vegetation, the wind becomes a potent factor (Figs. 1–2). Along the shore of Lake Michigan sand-dunes are destroying forests, and often when the forests have been cut off, fertile farms are covered by these great accumulations of wind-blown sand. In conjunction with sand, the wind builds or destroys islands. The loess * in China is a deposit of wind-blown soil.

In the desert of Sahara and in our great western plains great blinding storms of dust and sand occur. The sand, too heavy to be lifted more than a few feet high, is rolled along and drifted in wave-like mounds, which change their shape and position with the changes in the direction of the wind—just as the snow-drifts are formed in waves—and the particles sucked up into the whirling air, and redeposited in a new place by the force of gravity as the motion subsides. One of our "blizzards" is a good illustration of a sand-storm, only the substance transported by the wind is snow instead of dust and sand.

3. *Chemical Action.*—Another phase of atmospheric work is that of chemical action. Dry air

...ess - an extremely fine-grained soil. Some bluffs along the Mississippi River composed of it and then

FIG. I.—WIND-BLOWN SAND-DRIFTS.

FIG. 2.—PLANTING BEACH GRASS TO HOLD THE SAND AT CAPE COD, MASS.

has little chemical effect, but moist air is very active. The oxygen, which is now known to combine with nearly every other element, seeks to unite with the minerals of the exposed rocks.* Iron, which in some form is contained by most rocks, unites readily with oxygen in the presence of moisture, forming rust, which stains, softens, and ultimately causes the disintegration of the rock. Oxyge Iron

Carbon dioxide ($CO_2$), though present in a comparatively small quantity, is a powerful agent both in moist air and in rain-water. It acts upon the rocks, especially upon limestone, causing them to crumble away or to be entirely dissolved. $CO_2$

Demonstrat

EXPERIMENT I.—*Before beginning to perform any experiment in this book, read over the entire directions for it, get necessary apparatus ready, and know what you are going to do and why you are going to do it. Record your observations at the time they are made, not after leaving the laboratory.*

Throughout this book, wherever the word "*note*" is used, it means to *observe and record your observations or explanations.*

(*a*) Break pieces of limestone, marble, or clam-shells into tiny bits, and place a small quantity in a wide-mouthed bottle.

(*b*) Pour in small successive portions of dilute hydrochloric acid (HCl). Note what takes place as the acid comes in contact with the stones or shells. Both the hydrochloric acid and the calcium carbonate of the stones or shells are decomposed, and calcium chloride

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* Gilbert and Brigham, *Physical Geography*, p. 78.

($CaCl_2$), water ($H_2O$), and the gas carbon dioxide ($CO_2$) are formed. $CaCO_3 + 2(HCl) \rightarrow CaCl_2 + H_2O + CO_2$

(*c*) Now pass some of this gas, or carbon dioxide, from the bottle into the solution of clear lime-water (Fig. 3).

$H_2O = Ca(OH)$

(*d*) To prepare lime-water, dissolve common lime in pure water, let stand until clear, and carefully pour off the liquid, or pass it through a filter-paper. ‡ What takes place when the carbon dioxide passes into the lime water? Allow the gas to continue to pass, and note the result. $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + \begin{matrix}H\\H\end{matrix} \| + CO_2 \rightarrow H_2CO_3$

$CaCO_3 + H_2CO_3 \rightarrow H_2Ca(CO_3)_2$ (soluble)

(*e*) Boil the liquid, and again note result.

(*f*) Write up this experiment, stating the materials used, observations made, and what the experiment teaches, together with any further remarks or conclusions you may make concerning each step.

When the carbon dioxide was first passed into the lime-water, a precipitate of calcium carbonate ($CaCO_3$), or limestone, was formed.

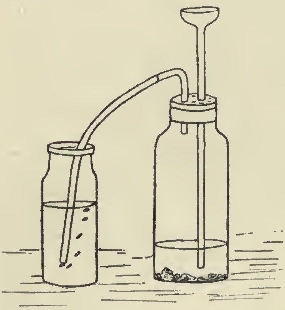

FIG. 3.—APPARATUS FOR EXPERIMENT I.

It continued to pass until there was no more calcium hydroxide, or lime-water, $Ca(OH)_2$, to combine with it, when the carbon dioxide united with the water ($H_2O$) to form carbonic acid ($H_2CO_3$). This acid at once acted upon the precipitate of calcium carbonate, forming a *soluble* bicarbonate of calcium, $H_2Ca(CO_3)_2$, which is dissolved, and the liquid becomes clear. The boiling drives out part of

Chemical law — Whenever a volatile compound can be

the carbon dioxide, and the calcium carbonate is again precipitated. formed, it is formed. Hence the $CO_2$ is driven off by

Other substances of the air which bear important relations to agriculture are nitrogen and its compounds, ammonia, nitrous and nitric acids, and ozone. 3 vols of O = 2 vols. of ozone. Same matter but combined a different amount energy

4. *Alternations of Heat and Cold.*—In dry, hot countries, rocks become excessively heated during the day and rapidly cooled at night. As the outer layer cools it contracts upon the hot and expanded interior, which tends to produce snapping and crumbling of the brittle minerals.

Thus we see the *work of the atmosphere* is constant; it is universal; it is not, however, uniform.* Both the rapidity and the extent of disintegration are dependent upon the differences of climate in various latitudes and altitudes, the differences in the rock substances themselves, the differences of seasons and of the amount of precipitation, and upon the presence or lack of protection from vegetation or soil.

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* The composition of the air varies greatly in different localities, or under different conditions in the same localities; but, under ordinary conditions, its constituents in a given volume are, approximately: oxygen, 20.6 per cent.; nitrogen, 77.18 per cent.; water vapor, 1.4 per cent.; carbon dioxide, .04 per cent.; argon, .78 per cent. The water vapor and carbon dioxide are the most variable. And there is present a variable quantity of ammonia, nitrous and nitric acids—a very small fraction of 1 per cent. altogether. .06 wt

$CO_2$ occurs in much larger per cent in soil than in air. Soil does not absorb $CO_2$ or N very readily but $CO_2$ is [illegible]

Begin 4th & 5th hour.

## II. Water.

Among the factors of soil formation none is greater than that of water in its various phases —as, rain, rill, river, lake, and sea; frost, ice, avalanche, and glacier.

1. *Chemical Action.*—In many of its forms water exerts a violent and stupendous force, but there is a silent and subtle force whose results are often overlooked. It is the great solvent power of water. It absorbs both oxygen and carbon dioxide from the air, and these give it great chemical power in dissolving, or decomposing, rock substances.* The simplest effects are the uniting of oxygen and of water with the minerals composing the rocks. But as the rain sinks into the ground it is provided with new weapons through the absorption of the humic acids and, possibly, of alkaline substances. For this reason, many rocks disintegrate more rapidly under ground than they do when exposed to the atmosphere.

Calcium carbonate, or limestone, is the substance dissolved or decomposed in the greatest quantity; but magnesium carbonate ($MgCO_3$), organic matter, silica ($SiO_2$), and many other substances are held in solution by clear river water. (See "Field Exercise No. 1," Part 2.)

* "Perfectly pure water has very little effect, but perfectly pure water does not exist in nature."—Scott's *Geology*.

The amount of these dissolved materials—though far less than that produced by mechanical action—is astonishing. That carried into the Gulf of Mexico by the Mississippi River annually reaches over 112,000,000 tons—not all derived from the river-bed, but taken up by the water from the time it falls in rain till it reaches the sea, whether it flows through the river and its branches, or whether it comes from springs or other underground sources.

2. *Mechanical Action.*—The mechanical action of water is threefold. (1) It disintegrates. (2) It transports. (3) It assorts.

The mechanical action of rain is due to the friction produced by the drops in striking the rocks, and by the abrasion of solid particles as they are carried to lower levels. It forms into little rills and gullies, washing out and carrying with it as it goes all the loose material which it can hold in suspension (Fig. 8). The amount thus obtained depends partly upon the solubility of the rock over which it flows (though even a granite would be slightly dissolved by ordinary rain-water), and partly upon the violence of the precipitation, and the volume and velocity of the stream.

The velocity is affected by several influences, but the greatest of them is the constant, never-failing action of *gravity*. Hence, the steeper the descent the greater the velocity. The

*power* is supplied by the volume and velocity of the stream, but the *work* of abrasion is performed, for the most part, by the sand, pebbles, and rock fragments as they are rolled along. They cut down into the river-bed, wearing it deeper; they polish each other into rounded or flattened shapes, or grind each other into powder in their mad rush to the sea.

= $V^6$
velocity = 1
TP = 1
velocity = 2
TP = 64

The *transporting power* of running water varies as the sixth power of its velocity, so that if its velocity be doubled it can carry sixty-four times as much solid matter as before. Thus it is that a slight increase in the velocity will greatly increase the load of a stream if the materials are obtainable, while the slightest decrease in the velocity will cause a part of the load to be deposited. These river deposits are commonly in sheets or bars, but when the river suddenly enters a plain at the foot of a steep slope an alluvial fan is formed by the deposition of the sediment.

According to the calculations of the United States government made many years ago, the Mississippi River transports to the gulf every year enough solid substance to make a column one mile square and 268 feet high—200,000,000 tons.

The student can find no better example of the carrying power of water than that of the roadside rills and gullies after a heavy rain.

assigned –

Experiment 2.—(*a*) Weigh a glass fruit jar, and collect in it the clouded or muddy water—from a gully or stream, after a rain—and allow it to stand until clear.

(*b*) Weigh again; then carefully pour off the water, and weigh the sediment remaining in the jar.

(*c*) Calculate the per cent. of sediment.

(1) Rivers.—When rivers overflow their banks the water loses its velocity, and a layer of sediment is deposited on either side of the stream. In the great rivers these flood-plains are broad fertile tracts of land very valuable for agriculture. Those of the Mississippi are many miles in width, but have to be protected from the overflowing of the river by levees.

Where the river empties into the quiet waters of a lake or sea the velocity is checked and the stream deposits its load. As the stream slackens the heavier particles are dropped first, and so on, until in the quiet waters only the finest silt is carried. Hence it is that, on lake or seashore, we find the coarser materials thrown down first, and farther out the finer sands (Fig. 4). There is usually a pause after such deposition is made until a fresh supply of sediment is obtained. This allows the surface to assume a somewhat different arrangement. This surface forms the plane of contact for the next layer, and is called the "stratification plane."

Demonstrat

Experiment 3.—The assorting power of water may be illustrated by (*a*) placing a mixture of rock material of

various sizes—pebbles, sand, clay, and vegetable mould—in a candy-jar, and nearly filling the jar with water.

(*b*) Now thoroughly stir the mixture, and allow it to stand until the water clarifies.

(*c*) Observe the arrangement of the sediment. Where are the largest pebbles found? Where the finest clay?

Of course the change here will be gradual, and

FIG. 4—DEPOSITION OF MATERIAL UPON SLACKING OF STREAM

the layers will not be so distinct, as there was no time for the formation of the stratification‡ plane between the depositions of different kinds of sediment.

(2) UNDERGROUND STREAMS.—Part of the water after a rain sinks into the ground. The natural breaks in the rock serve as channels which it may enlarge if the rock be soluble.

These underground streams perform various kinds of work, such as weakening rocks, dissolving minerals, carving channels, rising in springs or in artesian wells, bringing mineral matter to the surface, and forming caves and making peculiar deposits in them.

(3) LANDSLIDES are caused by the undermining of masses of rock and soil by water, which produces a slippery surface of bed-rock, and makes it easy for gravity to move an enormous quantity of soil or rock down the declivity.

(4) LAKES differ from oceans in being (usually) above the sea-level; in size; and in the freshness of their waters, provided they have an outlet. Their *chief movements are waves produced by winds.* These waves often erode the shore. They carry with them and distribute over the bottom of the lake the sediment brought by the rivers, thus making stratified rock.

(5) THE OCEAN, with its waves, tides, and currents, which constantly beat upon the shore, plays an important rôle in this great drama. As we have seen, the material transported by the rivers may form deltas and bars, or be widely distributed, according to the strength of the tides and the power of the currents along the shore. sedimentar-

More than one-half of the rocks have been rocks. laid down in the sea and then raised above it.

These deposits were not made out in the open sea, but near the shore in shallow water. Their thickness is accounted for by the theory that the ocean bottom was sinking gradually, and fresh deposits were made above the preceding ones.

In the open sea are found the deposits of very fine particles carried out by the rivers—on the continental slopes from the one hundred fathom line to the oceanic abysses—and they are known under the indefinite term of "mud." There are also volcanic deposits and great *accumulations of organic remains.* Every animal in the sea which has a shell or hard skeleton helps to make these deposits, but by far the greater part of them is made up of the shells of minute organisms* which live near the surface. The diatom ooze is composed of the siliceous remains of microscopic plants.

(6) Frost.—Frozen water has done a great share of the work in this process of mantling the earth with loose material. Some rocks are more porous than others, though those apparently solid will, upon examination, be found to be crossed by joints which divide them into blocks. These are filled with minute crevices and pores, through which the water percolates even to the very center. Water, upon passing

* Jordan and Kellogg's *Animal Life*, p. 18. Scott's *Geology*, pp. 176–180.

into a solid state, expands about one-eleventh of its original bulk. This expansion exerts an irresistible force, as is seen in the bursting of iron pipes, cracking the rocks into blocks, or shattering them into fragments, thus increasing their exposed surfaces many-fold, and exposing them to the action of other forces. -notebooks-

EXERCISE 1.—Let the student calculate the area of the exposed surface of a cubic foot of rock (*a*) before, and (*b*) after it has been broken up into cubic inches. (*c*) Compare *a* and *b*.

Another effect of the freezing of rock is to cause the fragments to "rise slightly at right angles to the inclined surface, and each thawing produces the reverse movement" * under the influence of gravity. Consequently, they slowly "creep" down the declivity (Fig. 5).

(7) ICE.—The ice of a stream expands with great force, pushing against the bank. It holds in its mighty grasp all loose stones, boulders, and trees along the banks, and when it breaks up transports them to great distances.

If the student has an opportunity, let him watch the breaking up the ice in a river, or even in a smaller stream, and see with what wonderful force the great blocks of ice with their burdens are crushing each other to pieces in the fury of a spring torrent. Iron bridges are often swept away by the enormous pressure.

* Scott's *Geology*, p. 82.

(8) SNOWSLIDES.—On the mountain sides great masses of snow which have accumulated through the winter become loosened by water, as in the case of the landslide, and are drawn down the slope with great momentum, carrying

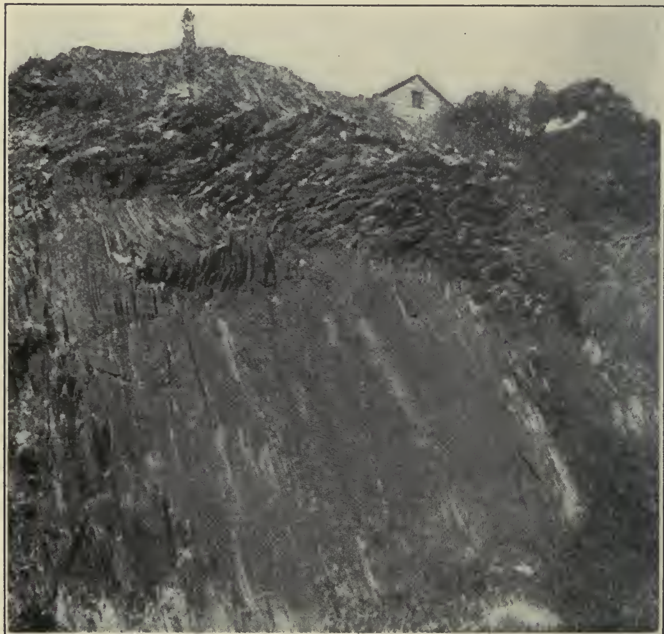

FIG. 5.—SHALES "CREEPING" UNDER THE ACTION OF FROST. (U. S. G. S.)

boulders, vegetation, everything within their path, and literally scraping the solid rock bare.

(9) GLACIERS.—It is now well established that in both North America and Europe glaciers, or great sheets of moving ice, existed in com-

FIG. 6.—FORMATION OF GLACIERS. (U. S. G. S.)

paratively recent geological times; indeed, they are found to-day, though in *much less size and number than formerly*.

The causes of the climatic changes which led to the formation and again to the disappearance of the glaciers are unknown. At the time of the great expansion these ice sheets covered nearly all of North America down to $40^\circ$ north latitude.

Wherever, in high latititudes or altitudes, more snow falls in winter than melts in summer, glaciers are formed (Fig. 6). These glaciers carry with them (1) upon their surfaces, (2) frozen in their interior, and (3) pushed along in front or beneath them, great quantities of rock of all degrees of coarseness, from the gigantic boulders weighing tons to the finest clay. Rocks over which they pass are striated and polished (Fig. 7), and both these and the materials carried may be ground into clay by the enormous pressure of the slowly moving mass. The *drift*, or this deposit, is distributed over vast tracts, and is stratified or unstratified. The stratified drift is deposited by the water of glacial streams, while the unstratified is simply dropped by the melting ice.

3 Types of Glac

At the present time there are great tracts of glacial ice: (*a*) the Alpine, occupying narrow mountain valleys, as those of the Alps; (*b*) the Piedmont glacier, like the Malaspina, of Alaska

FIG. 7.—ACTION OF GLACIER DRIFTS. (U. S. G. S.)

—lakes of ice formed by the union of many valley glaciers—which occupies an area of thirty by seventy miles, and which is covered along its southern border with morainic soil and great forests; and (*c*) continental glaciers, covering vast tracts, comprising hundreds of thousands of miles, like those in Greenland and the antarctic land.

(10) ICEBERGS.—When glaciers enter the sea fragments are broken off by the tide—some of them hundreds of feet in depth and more than a mile in diameter—and float thousands of miles before they melt and deposit immense quantities of rock.

ariation disin- gration + transportation

It is evident, then, that the disintegration and transportation of the loose material of the earth's surface by the various forms of water *vary greatly under varying conditions.* The chemical action is more rapid in warm, moist countries where vegetation is abundant, while the great variations of heat and cold in the temperate regions, and the powerful frosts in the arctic, render mechanical action more potent and swift.

Again, this work differs in its usefulness to the agriculturist. Sometimes a mantle of loose, workable material is deposited where a short time before the solid rock reached the surface, or great quantities of organic matter may be deposited which decay and enrich hitherto un-

productive soil. On the other hand, the hills, if unprotected by forest (Fig. 8), may be literally washed away by rain and gully, rivulet and stream, until fertile farms are transformed into sandy wastes.

Importance of forests, regulating erosion

*Field Exercise No.* 1.*

PART 1. *Work of Atmosphere.*—(*a*) Note any rocks worn away by the friction of rain or sand through the action of wind. Note any rocks kept exposed to other atmospheric agencies through the action of wind ; note any wind-blown soil; any wind-blown water; vapor.

(*b*) Note any evidences of chemical action; oxidation, hydration, action of carbon dioxide; "rotten rock." Draw a diagram showing successive stages of disintegration from solid rock to soil. (This diagram is to represent such a section actually observed in the day's excursion.)

(*c*) Note effects of changes of temperature—that is, alternations of heat and cold—upon rocks.

note too

PART 2. *Work of Water.*—(*a*) Note evidences of its solvent power. Fill a small bottle with *clear water* from a spring or brook, and when you return to the laboratory evaporate a few drops of it to dryness on a piece of glass or in a test-tube, and see if there is any residue; explain.

(*b*) Disintegrating Power of Water.—Note evidences

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* This outline is meant to be only suggestive of what may be actually seen in a field trip along almost any stream in the north Mississippi valley. Many of the points mentioned will apply to any locality of the United States; some will not. Neither will this outline include *all* that will be found in any excursion. The student will simply omit any points mentioned which he does not actually find, and insert under the proper headings any others found.



FIG. 8.—MECHANICAL ACTION OF RAIN.

of the washing out of loose material, and of the cutting power of water; of the abrasion performed by gravel, pebbles, and stones.

(*c*) Transportation Power of Water.—Why is one stream clear and another muddy? Note any sand or soil dropped by water.

(*d*) Note evidences of assorting power of water. Draw a section of the bank of a stream, showing stratification. notebook

(*e*) Note evidences of underground streams, of landslides, and describe and explain.

(*f*) Frozen Water.—Note work of frost, ice, glacier, and snowslides.

### III. Organic Life.

Beginning of life on earth

Everywhere myriads of living forms abound —in the air, in the water, on the land, and in the soil. However, there must have been a time when life did not exist upon the earth. It must have begun in a very humble manner, because the early conditions were such that complex organisms could not exist.

It is believed by both geologists and embryologists that from these simple beings have evolved in succession, through vast ages of time, all the higher and more complicated forms. Evolution

With the advent of life arose a new and mighty potency in the work of soil formation, and this force becomes the greater as life becomes more varied and complex.

1. *Plant Life.*—The fact that plants have

been from very early geological times, and still are, a powerful, though silent, factor in the processes of rock disintegration and soil formation is too often overlooked or underestimated.

Plant Life (1) MECHANICAL OR PHYSICAL EFFECTS.—Generally, wherever rock has been acted upon by the processes of weathering, vegetation creeps in. It may be some very low form, as fungus, moss, or lichen, but it sends its tiny root-like extensions into the crevices of the rock (1) and forces apart its particles.

In the higher forms of vegetation, where the roots are strong and woody, this becomes an important feature (Fig. 9). Huge boulders are burst asunder by the root-pressure of some giant tree; through innumerable rocky crevices larger or smaller root systems are finding their way, opening up the solid rock, and rendering it susceptible to other disintegrating forces (Fig. 9). In this same way myriads of grass roots and roots of herbs and forest trees are pulverizing the solid material of the soil.

While plants absorb water from the soil, at the same time, where vegetation is at all dense, they shield the earth's surface from the direct rays of the sun so effectively as to *retard evaporation*. (2) This retained moisture exerts a solvent power upon the rock substances.

Grasses, or other plants having thick, matted (3) roots, prove a great protection from the mechan-

ical removal of the soil (Fig. 10) by heavy rains or wind. Dense forests serve as windbreaks, and soil blown by the wind is lodged and prevented (4) from further transportation by the trees. These

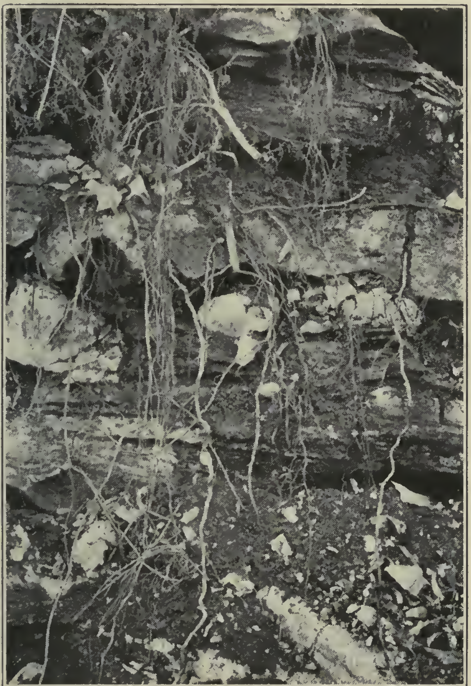

FIG. 9.—ROOTS OF FOREST TREES OPENING A ROCKY SUBSOIL.

forests, with their masses of roots and decayed leaves, also serve as a blanket in protecting from extremes of heat and cold.

Masses of seaweed act as barriers to the surf, (5) and the aerial roots of mangrove trees along

tropical coasts break the force of the waves, so that they cannot wash away the mud and sand.

ant Life (2) CHEMICAL EFFECTS.—The roots of living plants, from their acid secretion, effect a chemical action upon the insoluble substances with (1)

FIG. 10.—VEGETATION PROTECTING THE SOIL.

which they come in contact, rendering them soluble, and absorbing into themselves large quantities of certain compounds as plant food, thus depriving the soil of this material. That this acid secretion actually corrodes or dissolves rock material was proven by Sachs through actual experiment, which any one may also prove for himself. By the decomposition of vegetation (2) humic acids are formed, which have the power

of dissolving many minerals not soluble in rain-water.

Since plants can derive their food from much simpler elements than can animals, many scientists believe that the first forms of life were those of a very low type of vegetation. The only organisms which could exist upon a bare rock must be those which could subsist upon a purely mineral food obtained from the rock itself, and from the water and gases of the atmosphere. It has been discovered that even the denuded rocks of very high mountains are covered by a layer of organic matter, evidently formed by microscopic vegetation. These micro-organisms have even been discovered at considerable distance in the interior of these rocks. They begin the formation of humus,‡ and make it possible for other low forms of plant life to creep in, which, in turn, help to prepare the soil for the sustenance of chlorophyll-bearing, or green, plants. No putrefaction without Bacte

Bacteria.—The micro-organisms which are of most importance to agriculture are the bacteria which (1) oxidize nitrogenous substances, thereby forming nitric acid, and (2) those which reduce nitric acid to ammonia or to free nitrogen.

In the processes of *nitrification*, ammonia is $NH_3$ one of the first products formed from fermenting organic matter by one species of bacteria.

The ammonia ($NH_3$) is oxidized to nitrous acid ($HNO_2$) by another species; this in turn is changed into nitric acid ($HNO_3$) by still another species. In a similar manner the opposite process of *denitrification* goes on. First, the nitric acid is reduced to nitrous acid, this to ammonia, and then to free nitrogen, each step being performed, respectively, by a distinct species of bacteria.

Formation of Nitrates and Ammonia Salts

Both of these processes may take place in the soil, their extent depending largely upon the oxygen supply. In a well-aerated soil nitrification takes place, while in an undrained, poorly ventilated soil denitrification occurs.

Environment of Bacteria

It has been proven by modern science that the nitrifying organism of the soil is able to subsist in a purely mineral environment. Now certain bacteria, or soil ferments, are found in great numbers about plant rootlets—in fact, living in mutual relationship with them. It is, therefore, thought probable that the action of bacteria has an effect upon the mineral particles of the soil which renders them solvent and prepares them for absorption by plants as food.* (Year-book, 1895.)

Although these bacteria can subsist upon

* The value of leguminous plants for worn out or poor soils has long been realized, but not until 1888, when Helriegel published the results of his investigations, was the real source of their fertilizing power known.

minerals, they are far more flourishing in the presence of decaying organic matter. Indeed, their action is believed to hasten the decomposition of organic material. So it is that the plant, by its own decomposition, is through these agencies made to contribute to the formation of humus, which is an essential part of true soil.

(3) VEGETABLE ACCUMULATIONS OR DEPOSITS.—Not only does the living plant exert an influence upon the soil, but when it dies its remains form, though very slowly to be sure, accumulations of vegetable matter.

(*a*) True soil.—Vegetable accumulation is most important as well as most conspicuous as a mantle of true soil, formed from the decayed vegetation in the forests or grass-covered prairies.

(*b*) Wherever vegetation slowly undergoes decomposition under water *carbonaceous accumulations* are formed. The further decomposition proceeds the greater the per cent. of carbon; thus results peat, lignite, bituminous, or anthracite coal, according to the stage of decomposition reached.

(*c*) In fresh-water lakes and ponds, as well as in the sea, the siliceous cases of microscopic plants known as diatoms form considerable accumulations.

1. *Animal Life.*—Animals have a twofold

geological effect: (1) that of disintegration, and (2) that of accumulation.

(1) Disintegration.—In the sea even the hardest rocks are made to crumble by marine animals boring into them. In like manner many animals burrow and bore through the soil.

The *prairie dog* of the western United States digs a deep burrow in the earth, and casts up a mound at its entrance. There are whole villages of these mounds, which in some localities cover many acres. Muskrats, crayfish, moles, woodchucks, and gophers in countless numbers are performing similar operations.

Ants, especially in tropical countries, bring up sand grains from their underground tunnels, and form multitudes of ant-hills sometimes a foot or more in hight. Myriads of other insects, or their larvæ, pulverize the soil particles or enrich them with their excreta and decayed bodies.

But the most important of these animal agencies in stirring up, pulverizing, mixing, and ventilating the soil is that of the common earthworm. Darwin, in his investigations upon the earthworm, estimated that in many parts of England "more than ten tons of earth annually pass through their bodies and is brought to the surface on each acre of land." In this way the whole superficial bed of soil would pass through their bodies in a few years. The specific action

of earthworms has both a mechanical and a chemical effect. The burrows may extend several feet under ground, and are connected with each other by underground tunnels, so that the soil is thoroughly exposed to the chemical action of gases and acids of the air and water. The muscular gizzard grinds the stony particles swallowed by the worm, making them finer and more succeptible to the humic acids, the generation of which is probably hastened during the digestion of the vegetable mould and half-decayed leaves, upon which the worm feeds.

(2) ANIMAL ACCUMULATIONS.—Calcareous Deposits.—"The sea is constantly receiving from the land materials in solution, the most important of which are the carbonate and sulphate of lime. Many classes of marine animals extract the calcium carbonate ($CaCO_3$) from the sea-water and form it into hard parts, either as external shells and tests or as internal skeletons. There is also good reason to believe that some, at least, of these organisms are able to convert the sulphate into the carbonate." In shallow seas, where the conditions of warmth and food-supply are favorable, animal accumulations are developed on a large scale. The most important of these accumulations are those of the corals,* echinoderms, and mollusks.

* Scott's *Geology*, pp. 165–170.

Many immense limestone beds were accumulated from the shells of mollusks and the skeletons, or calcareous plates, of starfishes, sea-urchins, crinoids, and all sorts of lime-secreting animals. The forameniferal oozes formed from the calcareous shells of microscopic, unicellular animals of the deep sea have a vast geographical extent.*

Siliceous Deposits.—The Radiolaria are a group of microscopic animals which make siliceous secretions instead of calcareous ones.

ame deposits ?
outh Carolina

Phosphate Deposits.—These are terrestial formations derived principally from guano, which is composed of the excrement, bones, and remains of birds (or in caves, bats). They are found in rainless regions, like Peru and its islands. When the guano is deposited over limestone it gradually changes the limestone from a carbonate to a phosphate of lime.

3. *Environmental Changes.*—Beavers build dams across streams, and sometimes flood many acres of lowland. By felling trees they interrupt the drainage, thus forming marshes favoring the formation of peat beds.

Man also may change natural conditions, either purposely or incidentally, by planting or destroying trees, thus causing the protection (Fig. 11) or denudation of hillside slopes; by

* Jordan and Kellogg's *Animal Life*, p. 18.

FIG. II.—HOW THE FARM IS RETAINED.
(Division of Forestry, United States Department of Agriculture.)

plowing and harrowing, thereby exposing the soil to the action of the wind and rain ; by boring wells, and excavating mines and quarries; by controlling or directing the water of rivers and streams, and by irrigating dry or desert regions (Fig. 12), thus changing the natural environment very greatly if not altogether (Fig. 13).

4. *Field Exercise No. 2.*—A Study of Organic Life as a Factor in Soil Formation.

PART 1. *Mechanical Action.*—(*a*) Note the disintegrating processes of plant life. Pull off the moss, or lichens, growing upon a solid rock, and see how far beneath the surface the root-like extensions have crept. Measure and calculate the length of some great root-system which is exposed along the bank of a stream, or find rocks burst asunder by root action ; note examples of retarded evaporation.

(*b*) Note the protection of soil by plants.

(*c*) Note vegetable accumulations. In the woods, notice the formation of humus from the decayed leaves, twigs, and bark, and contrast the soil with that in the meadows, roads, and lawns. Account for these variations, and discuss all factors concerned, as sunlight, air currents, depth of feeding roots, and kinds of material obtained by them at the different strata. What is the relative value of the soil from each place? Take a sample of each of these soils back to the laboratory, and try to grow a plant of the same kind and size in each soil, and record and compare your results.

PART 2. *Work of Disintegrating and Pulverizing the Soil.*—(*a*) Describe the work of as many different kinds of animals as it is possible to find in your trip ; dig up a block of soil containing the burrows of earthworms,

FIG. 12.—VIEW OF AN IRRIGATING DITCH WHEN MADE.

FIG. 13.—VIEW OF SAME DITCH TEN YEARS LATER.

and make a drawing of both vertical and horizontal, or connecting, channels.

(*b*) Note any environmental changes made by man or other animals, or by plants.

(*c*) Note any fossils, or animal accumulations.

(*d*) Remarks and conclusions. (It is to be understood that any observation made under any of the foregoing heads is to be written up in its place, whether it is mentioned in this outline or not.)

[References after Chapter III.]

[illegible] acre — ft. of soil = 4 000 000 lbs.

# OUTLINE OF CHAPTER II.

## CLASSIFICATION AND PHYSICAL PROPERTIES OF SOILS.

### *A.*—KINDS AS TO DEPOSITION.

**I. Sedentary, or Residual, Soils.**

**II. Transported Soils.**

1. *Drift.*
   (1) Boulder Clay, or Till.
   (2) Stratified Drift.
2. *Alluvial Soils.*

### *B.*—KINDS OF SOIL AS TO DERIVATION.

**I. Sandy, or Siliceous, Soils.**

**II. Clayey, or Argillaceous, Soils.**

**III. Limy, or Calcareous, Soils.**

**IV. Humous Soils.**

### *C.*—PHYSICAL PROPERTIES OF SOILS.

Experiments 4, 5, 6, 7.

# CHAPTER II.

## CLASSIFICATION AND PHYSICAL PROPERTIES OF SOILS.

### *A.*—KINDS AS TO DEPOSITION.

See Notes Mar. 2 '0

**I. Sedentary, or Residual, Soils.**

These are formed where they lie by the weathering of the rocks which underlie them. They consist of those parts of the decayed rock which are not easily dissolved and carried away by rains.

These soils vary in depth. In certain localities the soil is only about seven feet thick, and poor in soluble compounds, such as lime. "In some parts of our Southern States the felspathic rocks are often found thoroughly disintegrated to the depths of 50 to 100 feet." *

The *nature* of residual soils depends upon the kind of bed-rock underlying them and the weathering. "Thus, limestones make the rich Blue-grass Region of Kentucky, and sandstones make the poorer part of the State." †

True soil, usually darker in color on account of the vegetable mould which it contains, and of the "oxidation and hydration of its minerals," forms the surface layer. Below it is the subsoil, which is often divided into layers, and some-

* Scott's *Geology*, p. 77.

† Gilbert and Brigham, *Physical Geology*, p. 87.

times contains great masses of the parent rock which have not been decomposed. By gradations the subsoil shades into rotton rock, and from this into solid rock.

**II. Transported Soils.**

The soils upon vast areas of the United States have not been formed from the rock formation which underlies them, but they have been transported thither over long distances by ice, or water, or wind (Chapter I.).

Ice

1. *Drift.*—Soils deposited by ice are called "drift," and may be distinguished by the presence of boulders. These soils usually consist of a variety of minerals brought together from different rock formations through the action of glaciers. Drift soils cover great areas in the United States north of the 39th parallel.

(1) Boulder Clay, or Till, is the unstratified material which covers the greater part of glaciated areas. It is composed partly of preglacial soils and stones pushed before the glaciers, and partly of finely pulverized rock gathered from the bed-rock by the grinding and scraping or the glacier itself.

(2) Stratified Drift is also found where it has been deposited by the water of glacial streams.

2. *Alluvial Soils* are those which have been transported by streams of water (Chapter I.). These are usually stratified, often differing

in the *kind* of rock material as well as in its state of disintegration. "The soils of the central valley of California have mainly come down from the Sierras by the wash of the rivers. The soils of Louisiana have been brought from the Rocky Mountains, from the great plains, from the prairies, and from the plateaus and mountains of the Appalachian region. They have been transferred by the Mississippi and its branches. The earthy mantle of Connecticut and Rhode Island is in part composed of rock flour and stones brought from Massachusetts and the northern New England States. The Connecticut and other rivers have done some of this work, but much more is due to the great glacier moving south over that region." *

### *B.*—KINDS OF SOIL AS TO DERIVATION.

As has been said, the basis of soils is disintegrated rock. Hence, the physical and chemical properties of soils depend upon the geological formation of the mass of rock from which it is derived.

If a deposit of quartz ($SiO_2$), which it is estimated composes one-half of the rocks of the earth, has been slowly disintegrated it will result in hard, distinct grains of sand, since quartz disintegrates with difficulty.

* Gilbert and Brigham, *Physical Geology*, p. 87.

**I. Sand.**

Sand is "light and open"—that is, easy to work. It absorbs very little moisture from the air. It has little power of chemically holding plant-food. Sandy soils are usually poor in phosphoric acid and potash, two important plant-foods.

**II. Clay.**

If a feldspar—which consists of silica, alumina, and one or more of the alkalies, potash, soda, or lime—has been disintegrated, clay will result. The term "clay," however, is very loosely applied to almost any kind of finely pulverized rock, or mud.

Clay soils are hard to work; they absorb moisture from the air readily. They contain, chemically, much plant-food, being often rich in potash and poor in lime and phosphoric acid.

Shale is a rock consisting of very thin layers. Its composition varies greatly, sometimes grading into limestone or finely grained sandstone. Shales form mud or clay.

**III. Calcareous Soils.**

Some soils are largely composed of carbonate of lime from the disintegration of limestone, which is a soft rock and one easily dissolved. Soils containing a large per cent. of limestone are called *calcareous soils*. Lime makes clay soils more easily worked and sandy soils more

FIG. 14.—FIFTH GRADE CHILDREN COLLECTING DIFFERENT KINDS OF SOIL.
(Kirksville State Normal School.)

compact. It hastens the decay of vegetable matter. Limy soils are poor in potash and often rich in phosphates (see "Lime," p. 95).

**IV. Humous Soils.**

The decaying organic matter in soils is composed of compounds of nitrogen, hydrogen, oxygen, and carbon, and is called "humus." Soils containing a large per cent. of this organic matter are designated as "humous soils." Humus gives a dark brown or blackish color to the soil. Leaf mould very largely consists of humus. Either a sandy or a clay soil is improved by humus, not only on account of the additional plant-food, such as carbon dioxide, ammonia, and water, which is furnished by its ultimate decomposition, but more especially on account of the improvement of the physical condition of the soil.

Humus absorbs and retains moisture, and thus improves a sandy soil. It improves a clay soil by making it less compact and better aerated. It improves the physical condition of worn-out soils.

Humous soils are often rich in nitrogen and poor in mineral plant-food. A soil formed from the addition of humus to a sand, clay, or calcareous loam is called a clay or argillaceous loam, or calcareous loam, according to the kind of soil which forms the basis.

## *C.*—PHYSICAL PROPERTIES.

EXPERIMENT 4. PART 1.—(*a*) Collect a quantity of dry sand, and one of dry clay, and one of dry garden loam. Keep these in a dry place in separate boxes for use in the following experiments.

(*b*) Get three small, similar-sized boxes, and fill each box with one of these soils.

(*c*) Weigh each one separately. Which is heaviest? Which lightest?

(*d*) How many cubic inches of soil in each box? What part of a cubic foot? How many square feet in an acre? How much would an acre of soil to the depth of one foot weigh if each cubic foot weighed the same as a cubic foot of your sample of garden soil?

(*e*) If this acre produced a crop of twenty-five bushels of wheat and 2,500 pounds of straw, how many pounds* has this crop taken from one acre of soil? This may seem a very small amount to be taken from the soil, but it must be borne in mind that some soils contain a very small per cent., or fraction of a per cent., of some of the very essential plant-foods (as, potash, phosphoric acid, or nitrates), while plants vary in their demands for these different foods. So it is that certain essential plant-foods, as nitrogen, may be nearly exhausted from a given soil by repeatedly growing certain plants which make large demands of that particular element from the soil, and yet the same soil may be abundantly able to sustain other plants which demand less of that element from the soil. †

PART 2.—(*a*) Place these three boxes (Part 1, *b*) of soils in a cool, dry place. With them place three similar

* At least 95 per cent. of the material composing the plant is obtained from the air and water, and but 5 per cent. from the soil.

† See "Leguminous Plants" and "Fertilizers."

avg. wt. of acre-foot of soil is 4 000 000 lbs.

boxes, each containing one of these soils, sand, clay, and loam, which has been thoroughly saturated with water.

(*b*) Put a thermometer with the bulb at the depth of two inches in each of these six boxes, and allow them to stand until the following morning; then record the temperature of each.

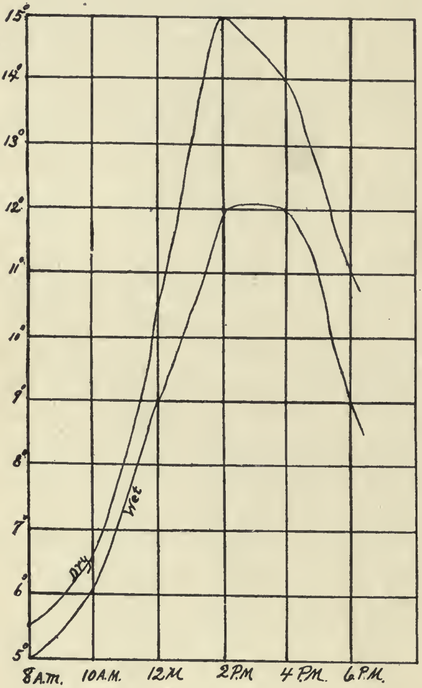


FIG. 15.—TEMPERATURE CURVES OF A HUMOUS SOIL.

(*c*) Place all the boxes where they will be equally exposed to bright sunlight, and note the temperature of each soil every two hours from 8 A.M. to 4 P.M., taking care to note whether the sun is under a cloud at the time of each observation.

(*d*) Upon a piece of co-ordinate paper indicate the temperature curve of each of these soils dry, and that of each of these soils wet, similar to that indicated for a humous soil in Fig. 15. In these curves (Fig. 15) the space between each two horizontal lines represents one degree, while that between each two vertical lines represents two hours.

Let the temperature curve of the loam be indicated by an unbroken line ——, that of sand by a broken line ----, and that of clay by a dotted line. . . . .

Compare. Give a reason for the differences in temperature between these soils.

(*e*) On the next bright day again saturate one box of each of these soils, and place the dry and wet soils in the bright sunlight. At noon record the temperature of each, and remove all to the shade indoors.

(*f*) Note the temperature at 2 P.M. and 4 P.M. Which soil, dry, retains the greatest amount of heat? Which soil, wet, retains the greatest amount of heat?

(*g*) What conclusion of practical value do you draw from your results? Could you improve the condition of any or all of these soils with regard to the absorption and retention of heat? How?

PART 3.—(*a*) Thoroughly moisten these soils, and try to mold a handful of each kind (sand, clay, loam) into some desired form.

(*b*) Which soil has the greatest power of holding its particles together? Which the least? Which soil will be most liable to puddle? Which most apt to bake?

(*c*) Mix each of these soils with one-fifth its bulk of lime, and repeat (*a*).

(*d*) Mix each with one-third sand, and repeat (*a*).

(*e*) Mix each with one-third humus, and repeat (*a*).

Of course, one could not apply sand, lime, or humus in quite such large proportions in the open field, but it could be done for house plants, and in smaller proportions in gardens and fields. Which of these soils would be improved for working by (*c*)? (*d*)? (*e*)?

EXPERIMENT 5.—(*a*) Procure three pieces of galvanized iron tubing of equal lengths and diameters—from two to two and one-half feet long, and from one inch and one-half to two inches in diameter (Fig. 16).

(*b*) Firmly fit in the bottom of each tube a plug of cotton.

(*c*) Weigh each tube separately, and then record the weights.

(*d*) Fill the tubes three-fourths full of *dried* sand, clay, and loam respectively.

(*e*) Carefully weigh each tube with its contents, and record the weights.

(*f*) Now fill each tube with water which has been leached from stable compost, taking care to record the *exact time* when the water *first* comes in contact with the soil.

(*g*) Support or suspend these tubes in an upright position (Fig. 16), and allow the water from each tube to drip into a separate vessel. Observe and record the time required for the water to begin to drip from each tube. Keep each tube filled with the leached water until the soil is saturated. Through which tube did the water pass most rapidly? This passage of water downward through the soil is called percolation.

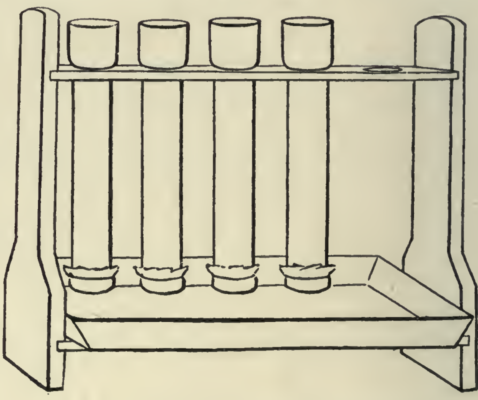

FIG. 16.—APPARATUS FOR EXPERIMENT 5.

(*h*) Compare the color and the odor of the water percolated. Through which of these soils will soluble plant-food most readily leach? Which soil will absorb the most plant-food from the water which percolates through it?

(*i*) Allow the liquid to drip for half an hour, and compare the water which now percolates through with that first percolated. Is it safe to depend upon the soil to act as a filter in purifying the water of wells from organic matter?

(*j*) Very carefully pour off all the water remaining in the tubes, and weigh each tube with its contents, record the weights, and compare with those of (*e*). Which soil retained the greatest amount of water? ✓

EXPERIMENT 6.—(*a*) Procure a set of capillary tubes 3 Cavel (Fig. 17)—four or five tubes—varying in diameter from a hair tube to one one-fourth inch in diameter.

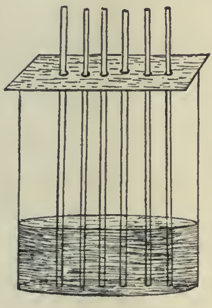

FIG. 17.—APPARATUS FOR EXPERIMENT 6.
Capillary rise of liquid not shown.

(*b*) Half fill a beaker, or tumbler, 4 Curty with water colored with red ink.

(*c*) In a piece of pasteboard punch several holes corresponding in size 5 Coll and number to the tubes used; thrust the tubes through the holes to three-fourths the distance, below, of the hight of the beaker. Now cover the beaker with this pasteboard, allowing the tubes to extend down into the colored liquid (Fig. 17).

(*d*) Note the hight to which the liquid rises in each tube. In which highest?

The wall of the tube attracts the film of water next to it, and tends to spread it out over the surface of the tube, overcoming the resistance of the surface tension of the liquid itself. Notice that the surface of the liquid both inside and outside of the tubes assumes a concave shape, on account of the creeping up of the liquid next to the wall, caused by the attraction between

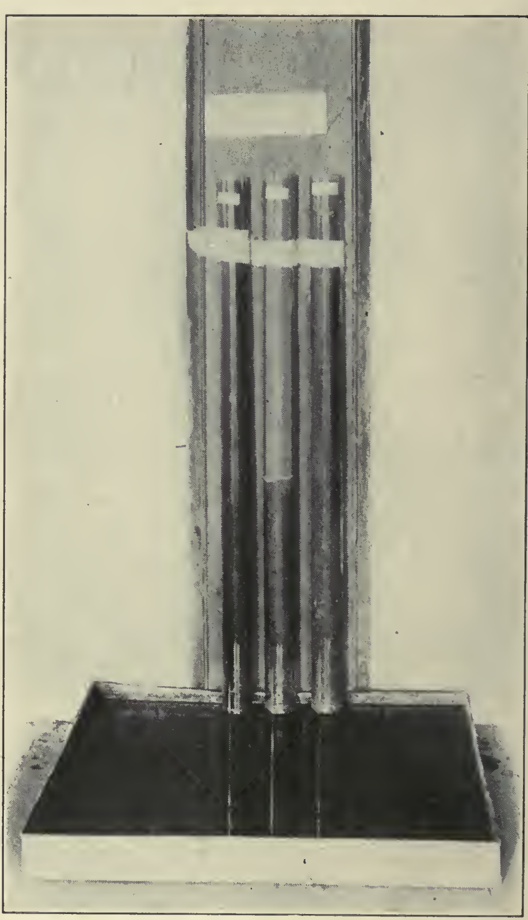

FIG. 18.—APPARATUS FOR EXPERIMENT 7.

the solid and liquid substances. (See any good physics for capillary action).

The pores in an open, or gravelly, soil act as the larger tubes, while the smaller pores of a

less open or more finely pulverized soil act as the fine tubes in conveying moisture.

EXPERIMENT 7.—(*a*) Take three glass tubes one and one-half inches in diameter and four feet in length * (Fig. 18). In the bottom of each of these tubes firmly fit a plug of cotton.

(*b*) Thoroughly pulverize the dried clay and loam. Firmly and evenly fill each tube with the sand, clay, and loam, respectively. Stand them in a pan of water with a layer of gravel in the bottom, and record the time of so doing. Keep the pan well filled with water.

(*c*) At intervals—from one to three hours during the first day or two—note the hight of the water in each tube. After the second day, once a day will be often enough to make observations.

(*d*) Continue the observations and records until the water no longer rises in any tube.

(*e*) In which tube did the water rise most rapidly? In which to the greatest height? *This power of drawing water upward through the soil is called capillarity.*

EXERCISE 2.—From the data obtained in performing these experiments, write up the *physical properties* of each of these three kinds of soil. Your description of each soil should cover the following points: Color, weight of a cubic foot, light or heavy to work, power to absorb heat, power to retain heat, power of holding soil particles together, porosity, power to absorb and retain water, capillarity, and any remarks.

[References after Chapter III.]

* Straight lamp-chimneys may be substituted for the long glass tubing. It is more economical, and will give satisfactory results.

# OUTLINE OF CHAPTER III.

## SOIL MOISTURE AND PREPARATION OF THE SOIL.

### *A.*—SOIL MOISTURE.

**I. Kinds of Moisture.**

1. *Ground Water.*
2. *Capillary Water*
3. *Hygroscopic Water.*
   EXPERIMENT 8

**II. Relation to Plants.**

1. *Dissolves Plant-food.*
2. *Conveys Plant-food.*
   EXPERIMENT 9.
3. *Constitutes Plant-food.*
   EXPERIMENT 10.
4. *Tends to Regulate Temperature.*

**III. Field Exercise No. 3.**

### *B.*—PREPARATION OF THE SOIL.

**I. Drainage.**

EXPERIMENTS 11 AND 12.

**II. Irrigation.**

EXPERIMENT 13.

**III. Preparation of Seed-bed.**

1. *Plowing.*
2. *Surface Tillage.*
   EXPERIMENT 14.

### *C.*—REFERENCES.

# CHAPTER III.

## SOIL MOISTURE AND PREPARATION OF THE SOIL.

### *A.*—SOIL MOISTURE.

It is evident from the foregoing experiments that the particles of soil and, therefore, of the spaces between them, vary in size. When the soil is dry most of the spaces are filled with air, but when the soil becomes wet the air is driven out by the water.

**I. Kinds of Moisture.**

1. *Ground Water.*—The water which percolates through the soil under the influence of gravity until it reaches an impervious layer of hard-pan, or rock, is called the free or ground water of the soil. Above the hard-pan, or rock, is a layer—varying in thickness—of saturated, or water-soaked, soil. It is from this free water that the supply is obtained for springs and wells. In dry weather it is drawn upon by capillary action to furnish the moisture for vegetation, but if this free water is allowed to stand too near the surface of the soil it is injurious to most plants. In soils of close texture it becomes necessary to remove the surplus water by drainage.

2. *Capillary Water* is that which is held in the spaces between the soil particles by capillary

attraction, or the overcoming of the influence of gravity by the adhesion between the water and the solid particles, and is of direct use to plants.

3. *Hygroscopic Moisture.*—Each particle of soil is surrounded by a film of moisture, or hygroscopic water. It is held so firmly that even roadside dust contains this film.

Experiment 8.—Fill a test-tube one-third full of dry roadside dust; heat it gradually to a high temperature. Allow it to cool, and see if any moisture condenses upon the tube.

### II. Relation to Plants.

1. *Dissolves Plant-food.*—This surface film of water, through the carbonic and humic acids which it contains (Chapter I.), acts directly upon the plant-foods locked up in the soil, dissolving the mineral substances and giving them up to the surrounding capillary water.

2. *Conveys Plant-food.*—As has been seen, solids have an attraction for liquids. It is also true that denser or thicker liquids have an attraction for thinner ones; so it is, as the moisture is evaporated from the leaves and green bark of plants, leaving behind the solid substances, the fluid in the plant becomes denser than the soil water, and there is thus established, through the cell wall of the plant, a flow of the thinner liquid, or soil water, toward the denser protoplasm of the cells. This process is called

*osmosis*. Thus the soil water not only *dissolves* the plant-food, but through capillary action and osmosis actually carries this food to the plant.

EXPERIMENT 9.—(*a*) Take any single-stemmed growing plant, place the roots in a wide-mouthed bottle half full of water.

3 Clark
4 Green
5 Dunca

FIG. 19. — APPARATUS FOR EXPERIMENT 9.

(*b*) Make the bottle air-tight (to avoid the evaporation of the water) by splitting a cork into halves, hollowing out the center, and fitting them about the stem of the plant; now fill any crevice about the stem, or in the top of the cork, with melted paraffin.* Invert the bottle to see if any water escapes; if so, the cork is not fitted air-tight, and melted paraffin must be applied where it leaks.

(*c*) When the bottle is air-tight weigh it, and record date and weight. The following day place it where the plant will be exposed to direct sunlight, and weigh every day or two for two or three weeks. How much water has the plant used? Of what use to the plant was the water?

Hellriegel, through his experiments, found

* Paraffin melts at a low temperature, and will not injure the plant if carefully applied.

that the amounts of water evaporated from the soil and given to the air almost wholly through the plant were: by barley and red clover, 310 pounds of water to one pound of dry matter produced; oats, 376 pounds; peas, 273 pounds; and buckwheat, 363 pounds to one pound of *dry* matter. Plants differ in their demands for water, hence some kinds of plants are found upon dry soils and others upon wet soils.

3. *Constitutes Plant-food.*—Water itself constitutes an important plant food.

EXPERIMENT 10.—(*a*) Secure some green but well-grown plant (roots and all), as clover, corn, or cow-peas; carefully remove the soil from the roots.

(*b*) Weigh the plant accurately, and record the weights. 15.5 - 2.25   91% Loss.

(*c*) Hang the plant in a warm, dry place for two or three weeks, or until perfectly dry.

(*d*) Weigh again, and record weights. What per cent. of the plant was water? What per cent. dry matter?

4. *Tends to Regulate Temperature.* — The water which percolates through the soil from spring rains is warmer than the soil and tends to raise the temperature, while that from summer rains is cooler than the soil and tends to lower the temperature.

**III. Field Exercise No. 3.**

(*a*) Let the student look for different kinds of soil—as, dry, sandy soil, and wet soil—in the vicinity.

(*b*) Note (observe and list) the kinds of wild or cultivated plants growing upon each kind of soil. Do some plants thrive in one soil which are not found in others?

(*c*) If a farm contain certain areas of each of these kinds of soil, what use can the farmer make of this suggestion of Nature? Are any of the same kinds of plants found upon all of these soils? If so, compare their conditions.

(*d*) Can you give reasons for these conditions? In which soils can the air enter freely? Which with more difficulty? Which gives the best support in time of storms? Will each soil require the same treatment?

Experiments 9 and 10 show how essential soil moisture is to plants. Water and air not only furnish 95 per cent. of the food of plants, but the remaining 5 per cent. cannot be obtained from the soil except through the agency of air and water. Heat and light are also important factors in plant growth. It has been shown that soils vary in the power to admit air, and in the power to absorb and retain heat, and that the condition with regard to soil moisture affects these variations. The farmer can, by proper methods of drainage and tillage, greatly modify or regulate these *factors of plant growth*—water, air, and heat—in the soil. It is evident that different soils require different methods, and that the same soil requires different treatment for different plants. Tillage does not add plant-food to the soil, but it does render food already in the soil available to the plant.

### *B.*—PREPARATION OF THE SOIL.

The first thing for a farmer to do, and then to continue doing, is to *study his soils*, taking into

consideration the climate. The next thing to do is to consider what crops are best adapted to the different soils, remembering that both the immediate crops and the condition of the soil for future crops are to be regarded. Thus follows the consideration of the treatment of each kind of soil for the crop selected or *the preparation and tillage of the soil.*

### I. Drainage.

EXPERIMENT 11.—(*a*) Take two eight-inch flower-pots and label them 1 and 2, respectively. In No. 1 pour a sufficient amount of melted paraffin in the bottom to plug up the hole, so that no air may pass in, and no water pass out through the bottom of the pot. In the bottom of No. 2 place a layer about an inch in depth of stones or pieces of broken pottery.

(*b*) Nearly fill each pot with a mixture of three-fourths good soil, thoroughly pulverized, and one-fourth sand.

(*c*) Place in each pot a young, healthy plant of the same size and kind.

(*d*) Now carefully sprinkle each with water until the soil is saturated.

(*e*) After a day or two put these pots in a sunny window.

(*f*) In each place a thermometer, with the bulb at a depth of two inches.

(*g*) Every two or three days note the temperature, and the condition of the soil and of the plants in each pot. In which pot does the water percolate through the soil the more rapidly? If each of these conditions of soil moisture was found in separate fields, which field would be more apt to be flooded in time of heavy rains? In which could air penetrate the more readily? In which would the temperature be higher?

undrained 21° C

drained. 19° C

(*h*) At regular intervals—say, every two or three days—apply equal quantities of water to each of these pots.

(*i*) In about five or six weeks remove the soil—plant and all (see "Propagation of Plants")—and note the depths to which the roots have penetrated. In which have they gone the deeper, the drained or undrained soil? If these conditions of soil moisture existed in the open field in early spring, and were followed by a drought, how would these root systems compare in aiding the plant to withstand it? In nature, when these root systems die, how would they compare in affecting the porosity of the soil? How would such soils affect the nitrogen-fixing bacteria (Chapter I.)? How would the work of earth-worms, grubs, and other burrowing animals compare in these two soils?

Soils having a loose and open subsoil are naturally underdrained, and do not need to be artificially drained. Soils of fine texture, or those having a clay or hard subsoil, do not allow the free water to percolate through them, and it stands very near the surface, unless artificially drained. It is not as the water passes down through the soil that it is carried away by drains, but as it rises again in saturating the soil above the impervious layer of hard-pan or bed-rock. The deeper the drain the greater the area drained, hence the wider apart the drains may be. [illegible]

Experimnt 12.—(*a*) Procure a keg, or barrel, which does not leak, and in its side bore two or three holes, one above the other, about twelve inches apart, the first hole being six inches from the bottom.

(*b*) Nearly fill this keg, or barrel, with soil. Shake it down firmly.

(*c*) Gradually pour water into the center of the keg—where the soil should be, perhaps, a little lower—until it runs out of some one of the holes.

According to your result, which would carry off the water first—a shallow or a deep drain?

In shallow drains there is danger that the tile may be injured by frost. The depth to which a drain should be laid depends upon the character of the soil; the more compact soil requires more numerous and shallower drains. Three or four feet deep and one hundred feet apart are sufficient for ordinary farm crops. "The carrying capacity of tile varies with the square of the diameter." * In every drain the tile should increase in size as the quantity of water increases. Tile varying from three to six inches, with larger size for mains, are generally used.

Since tile-drains admit more or less atmospheric air, as the temperature and pressure of the atmosphere rise and fall, the circulation of the air is produced below the roots of plants as well as above them.

### II. Irrigation. Hilgard p. 239.

Experiment 13.—(*a*) Procure a box about three feet long, one and one-half wide, and one foot deep.

(*b*) In the center of one side, near the bottom, bore a hole, and fit into it a cork (Fig. 20).

(*c*) Nearly fill the box with dry, pulverized soil, and shake it down well.

(*d*) Now make a shallow trench in the soil, across the

* *Soils and Crops*, Morrow and Hunt, p. 66.

center of the box, and slowly pour water into it, until the soil at the bottom of the box is moist, as determined by removing the cork, and thrusting a rod, or straw, into the hole.

(*e*) Now, beginning at each side of the trench, remove a layer of the soil three inches in depth, noting carefully just how far the water has extended from the trench by lateral capillary action.

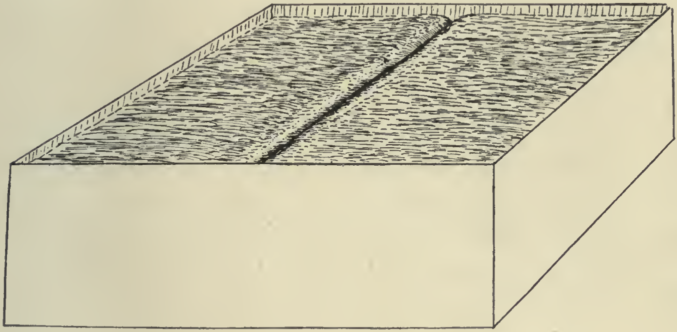

FIG. 20.—APPARATUS FOR EXPERIMENT 13.

(*f*) Remove another layer of soil three inches in depth, and note the lateral extension of the water at this depth.

(*g*) Remove a third layer three inches in depth, and note again. Compare the lateral extension of the water at each of these depths with that of the other two.

It is upon this principal of lateral capillary action that irrigation is based.

### III. Preparation of the Seed-bed.

1. *Plowing* is done before planting (1) to destroy weeds by completely covering them; (2) to bring plant-food to the surface; (3) to pulverize and aerate the soil; and (4) to allow the

water to percolate through the soil instead of running off of the surface. Plowing should never be done when the soil is wet enough to puddle.*

A soil which is loose and open, or one having a sandy subsoil, does not require such deep plowing as a mere compact soil. If the soil is wet and not underdrained, plowing may only increase the supply of ground water. If it is desired to deepen a soil, it is best to plow a little deeper each time, so that the portion of subsoil brought to the surface will not be sufficient to materially injure the character of the soil for the immediate crop. A small amount can be more readily acted upon by the weathering agencies than a greater amount can be.

Plowing at different depths prevents the formation of a hard-pan by the tramping of the horses at the same depth in successive plowings. On the other hand, if the soil is very porous, it may be prevented from leaching by plowing at the same depth to form this hard-pan, thus keeping the free, or ground water, within the reach of plants. If deep-feeding plants—as, alfalfa, clover, or vetch—are to occupy the land, it should be *deeply* plowed, and thoroughly pulverized.

In *early spring shallow* plowing is usually preferable, as the deeper soil is not so warm

* See "Propagation."

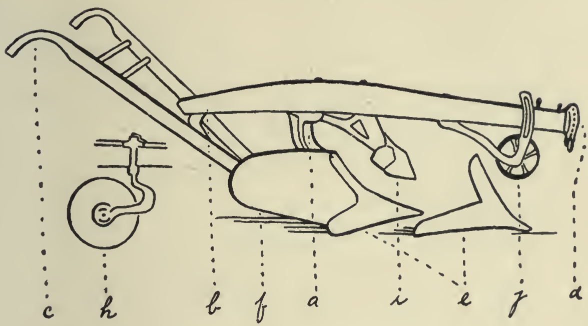


FIG. 21.—A GOOD PLOW.

*Parts of a Plow.—a.* The *standard*, or *stock*, to which many parts are attached.—*b.* The *beam*, by which the plow is drawn.—*c. Handles.—d. Clevis.* By placing the ring in the upper holes of the clevis, the plow is made to run deep; by placing the ring in the lower holes, the plow is made to run shallow; by moving the clevis to the right, the plow is made to cut a wider furrow.—*e.* The *share*, which cuts the bottom of the furrow slice.—*f.* The *mouldboard*, which turns and breaks the furrow slice.—*h.* The *coulter* which, when fastened to the beam, just in front of mouldboard, cuts the furrow slice from the land, and in disk-form is useful in turning under weeds.—*i.* The *jointer*, which skims stubble and grass from the soil, and throws them into the bottom of the furrow to be completely covered, and helps to pulverize the soil.—*j.* The *truck*, or wheel, attached to the end of the beam which steadies the plow and lightens the draft.

nor so dry as that near the surface. For winter wheat, if the ground has been plowed in the spring, it will require only shallow plowing, or, if an open soil, disking may be sufficient.

If plowing is for the purpose of drying and warming the land in the early spring the furrow slices should not be turned down flat, but allowed to incline at an angle to allow the air

and heat to enter. The same plan is beneficial if the plowing is done in the fall, as the rains

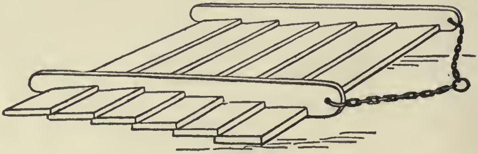

FIG. 22.—A PLANK HARROW.

will percolate through the soil instead of running off of the surface.

2. *Surface Tillage.*—Plowing should be followed by surface-working tools, to pulverize the

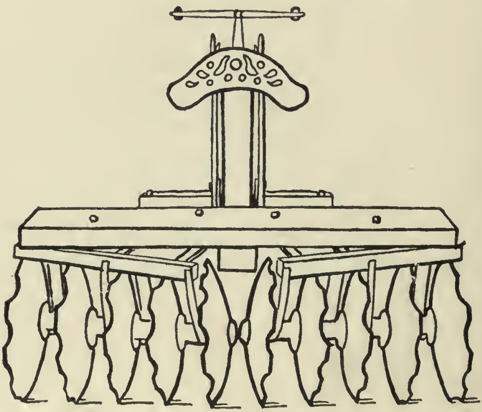

FIG. 23.—A ROLLING CUTTER HARROW

the ground and to prepare an earth mulch. The first surface tillage to follow the plowing should be done before the ground becomes too hard and dry with a heavy, coarse tool to crush

the clods, as a drag, or planker, or *rolling cutter* harrow (Fig. 23), or *spring-toothed* harrow

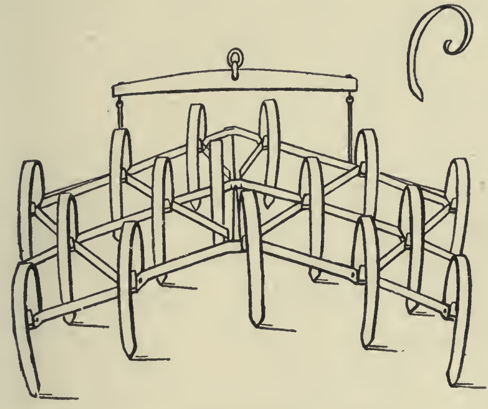

FIG. 24.—A SPRING-TOOTHED HARROW.

(Fig. 24). The seed-bed may be completed by a fine-toothed, lighter harrow, or a *coulter* harrow (Fig. 25), which "cuts, turns, and pulverizes" the soil.

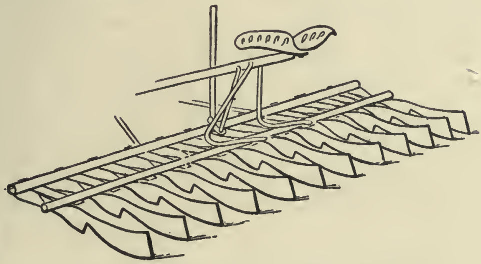

FIG. 25.—A COULTER-TOOTHED HARROW.

The roller is not used so much as formerly, since it leaves the soil in such a condition that capillary water may rise to the surface. Plank-

ers* (Fig. 22) are usually better than rollers, since they grind the clods instead of pushing them down into the soil, and make a smooth surface for seed-bed. Rolling after planting may aid the germination of the seeds in dry weather, as it brings the moisture within their reach; especially is it beneficial in the case of fine seeds. Rolling compacts the soil (hence it benefits a light, open soil), but should not be practiced upon *a heavy or wet* soil.

Chem. Lab.

EXPERIMENT 14.—(*a*) Take four gallon-cans, or paint buckets, label them 1, 2, 3, 4. Make several holes in the bottom of each, and put a layer of coarse stones, or pieces of broken pottery, in the bottom.

(*b*) Fill cans 1, 2, and 3 to within one-fourth inch of the top with mellow soil, and can 4 to within three inches of the top. Firm the soil well in each can.

(*c*) Stand all of them in water until the surface soil becomes moistened. *How* does the surface become moist? In field conditions, how would this supply of moisture be obtained?

(*d*) Take them out of the water and allow them to stand until the surface is dry enough to work. Leave No. 1 as it is, and carefully pulverize and loosen the soil in No. 2 to the depth of two inches, and that in No. 3 to a depth of three inches, and cover No. 4 with a three-inch mulch of sawdust or straw.

(*e*) Weigh each can separately, and record the weights.

(*f*) Place all under similar conditions—if possible, in an open window, or where the air will pass over them freely.

* *Fertility of the Soil*, Roberts, p. 103, and *Principles of Agriculture*, Bailey, p. 75.

Cult^n should be deeper in Calif. than in east-
n increase in depth of cult^n of 3 inches con-

(*g*) Allow them to stand until the surface of the soil in can No. 1 is dry. Weigh again, and compare with (*e*).

(*h*) Carefully dig down into the soil of each can, and measure the distance from the surface to a layer of moist soil. Compare these distances. In which can would the conditions be better adapted to surface-feeding plants? In which to deep-feeding plants? *How* does the water escape? Out of which can has it escaped most slowly? Most rapidly? Why? In which can the air most freely enter the soil? In outdoor soils of these three conditions, which would *now* allow the water to pass into it least freely? Which of these soils represent a rolled soil? Which a loosely tilled soil? How would a rain affect each of these soils? Why is it necessary to till the soil about growing plants as soon as possible after a rain? What is the condition of soil in the field in early spring? How does early spring plowing affect the evaporation of soil moisture?

(*i*) Compare these mulches, and record *your own* conclusions upon the teachings of this experiment.


FIG. 26.—TO SHOW THE EFFECT OF DEEP AND SHALLOW PLOWING.

Tillage for surface-feeding roots may be deep when the plants are quite young, but when they have made considerable growth plowing must necessarily be shallow to avoid destroying the roots (Fig. 26), which sometimes reach from row to row.

Cultivation should not be repeated until the

soil is reduced to too fine a dust, for it is apt to puddle when it rains, and exclude the air. Tillage also keeps down the weeds, which would rob the soil of plant-food and exclude heat and light.

## *C.*—REFERENCES FOR CHAPTERS I., II., AND III.

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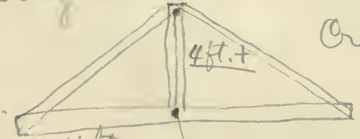
...lton River Basin — miss

East River clay alkali
Silt soil - sand + clay.
River water { K, $P_2O_5$ }

Irrigation ditches on contour—




Crude leveling device.

# OUTLINE OF CHAPTER IV.

## THE SOIL AS RELATED TO PLANTS.

### *A.*—USES OF THE SOIL TO PLANTS.

**I. It Serves as a Foothold.**

**II. It Affords Plant-food.**

**III. It Acts as a Storehouse for Water.**

**IV. It Retains and Regulates the Heat.**

**V. It Serves as a Habitation for Soil Bacteria.**

### *B.*—CONSTITUENTS OF PLANTS.

**I. Chemical Analysis of Plants.**

**II. Sources of Plant-food.**

1. *Air-derived Elements.*
   (1) CARBON.
   (2) OXYGEN.
   (3) HYDROGEN.
   (4) NITROGEN.
2. *Soil-derived Elements.*
   (1) PHOSPHORUS.
   (2) POTASSIUM.
   (3) Calcium

### *C.*—FERTILITY OF THE SOIL.

**I. Chemical Analysis of Soils.**

**II. Vegetation Experiments.**

**III. Fertilization of the Soil.**

1. *Commercial Fertilizers.*
   (1) NITROGENOUS COMPOUNDS.
   (2) PHOSPHOROUS COMPOUNDS.

(3) Potassium Compounds.
(4) Table of Fertilizing Materials.
(5) Lime. Exercise 4.

2. *Stable Compost.*
(1) Value in Furnishing Plant-food.
(2) Shameful Waste.
(3) Effects Upon the Soil.
(4) Protection and Application of the Compost.

## D.—REFERENCES.

Gypsum + salt 4 times as soluble as gypsum alone.

# CHAPTER IV.

## THE SOIL AS RELATED TO PLANTS.

### *A.*—USES OF THE SOIL TO PLANTS.

**I. The Soil Serves as a Foothold.**

The roots penetrate the soil and brace the plants against the wind, and hold them erect so that they more readily obtain air and light. The necessity for this support is made greater by the elongation of the stem in the struggle for light.

**II. It Affords Important Food Elements.**

Although but 5 per cent. of the food supply of plants is obtained from the soil, it does not follow that this 5 per cent. may be omitted. On the contrary, many of the soil-furnished elements are *absolutely necessary* to the life and development of plants.

**III. The Soil Acts as a Storehouse for Water,** so that the plant may draw upon its supply continuously, or much more nearly so than if it depended only upon the moisture obtained from the air and from that obtained for immediate use from rains. This soil water is invaluable both as a food and as a solvent for other constituents of plant-food, since plants can only take up substances which are soluble in the soil

water (which usually contains organic acids), or which may be rendered soluble by the acid reaction of the roots.

**IV. It Tends to Retain and Regulate the Heat** of the sun, and transform it into energy which plants can use.

**V. It Serves as a Habitation for Soil Bacteria,** which transforms the unavailable free nitrogen of the air into nitrates available for the use of plants.

### *B.*—CONSTITUENTS OF PLANTS.

**I. Chemical Analysis of Plants.**

Many analyses of the tissues of different plants have been made (though by no means of all plants), and through these analyses it has been ascertained that one plant may contain certain compounds—or particular combinations of these elements—which do not exist in some other plants. These analyses show that all plants are essentially made up of fourteen elements, or about that number.

**II. Sources of Plant-food.**

Four of these elements—carbon, oxygen, hydrogen, and nitrogen—are obtained directly or indirectly from the air, while the soil must supply the remaining ten elements: iron, calcium, silicon, chlorine, sulphur, phosphorus, potassium, sodium, magnesium, and manganese. The food elements obtained from the soil are the

P. K. Ca

C O H N | S, Mg, Fe, Cl Si Mn, Na

more numerous, but they form a very small per cent. of the quantity of plant tissues (not over four or five per cent. altogether), while the elements obtained indirectly or directly from the air form 95 per cent. or more of the quantity.

1. *Air-derived Elements.*

(1) CARBON.—Nearly half of the solid material of plants is carbon. It is found in the oils, starch, sugar, and albuminoids.‡ The leaves take in carbon dioxide from the air and decompose it (in the light) into its elements, carbon and oxygen, building up other compounds with the carbon and giving off the greater part of the oxygen.

(2) OXYGEN too may be directly taken from the air by leaves, buds, and flowers, or by the roots. It is also taken in in large quantities in the water absorbed. Oxygen forms a part of nearly all the compounds found in plants.

(3) HYDROGEN, in combination with oxygen forming water, is an important element in plants. There is no other compound so abundant in plants as that of water, and none whose function is more important, since it holds in solution other elements, or compounds, of plant-foods, and acts as a medium for transporting them to every tissue and cell of the plant.

(4) NITROGEN is an essential element in all the green and woody parts of plants—in fact, of all the protoplasm, or living substance, of the plant.

Insufficient available nitrogen. Sufficient available nitrogen.

FIG. 27.—SHOWING EFFECT OF NITRATE.

It promotes vegetative growth rather than fruitfulness. The presence of sufficient nitrogen available* to the plant—unless counteracted by some phosphate—is manifested by the vigor and deep green color of the leaf, with possibly retarded flowers and fruit, while the lack of available nitrogen is shown by scanty and pale foliage. The quantity available greatly affects

* *Available* plant-food is in such form that the plants can and will use it.

the amount of nitrogen stored up in the plant, and thus the excess access or lack of available nitrogen largely modifies the nutritive value of the plant as food for animals.

Four-fifths of the atmosphere is composed of this element so important to plant life, but most plants can be supplied root and branch with an abundance of nitrogen gas and yet starve for the want of nitrogen; for no green plants can take in free nitrogen. It must be combined with other elements in such a manner as to form compounds soluble in the soil water, so that it may be taken up by the roots.* The nitrates and ammonium salts are such compounds. There are certain kinds of plants which are intimately connected with particular forms of bacteria. This relation † is mutually beneficial. The bacteria work upon the roots of the plants, forming nodules (Fig. 28), and in turn convert the free nitrogen of the air in the soil into soluble nitrates for the use of the plant hosts.‖

Since most plants do not have access to the exhaustless supply of nitrogen afforded by the air, and there is only a small per cent. of available nitrogen in ordinary soil, and since nitrogen

* "Some plants absorb through their *leaves* a very small per cent. of ammonia directly from the air."—*Year-book*, United States Department of Agriculture, 1901.

† Symbiosis.

‖ See "Leguminous Plants."

is so essential to plant growth, it must be supplied in some other way. This phase of the subject will be further discussed under "Fertilizers."

All of the food elements obtained from the air, except nitrogen, are directly available from that source, so need no further mention.

2. *Soil-derived Elements.*

Of the ten elements obtained from the soil, all except phosphorus, potassium, and lime are present in sufficient quantities, and in such form as to supply the needs of plants, except in special cases.

(1) PHOSPHORUS.—It has been proven by repeated experiments that phosphorus in the form of phosphates * is essential to the healthy development of plants. Growth cannot take place without the presence of phosphorus in the nucleus of the cells. It helps in the assimilation of other food, induces seed-formation and the maturity of the plant, and assists in transferring the albuminoids to the seed.

The presence of phosphorus in an available form, if uncounteracted, is manifested by early maturity and plump, well-filled seeds. Ordinary soils are in time impoverished of the natural supply of available phosphates unless a portion

* "It has been well established that the salts of phosphoric acid—or *phosphates*—are the only source from which phosphorus of plants can be derived."—*Bulletin* 94, Maryland Agricultural Experiment Station.

FIG. 28.—TUBERCLES ON VELVET BEAN PRODUCED BY INOCULATION.

of that taken up by repeated crops, particularly of grain, is in some way returned to the soil. This plant-food (phosphate) also will be further discussed under "Fertilizers."

(2) Potassium.—Pure potassium is a silvery white metal, but it does not exist in nature uncombined with other elements. Potassium compounds are important ingredients in the formation of starch in the leaves and the transference of starch to the fruit. Since starch is so important in the formation of wood, it follows that the salts of potassium are essential to the development of the firm, woody tissue of the stems. Potassium forms the base of the acids of fruits and over half the ash of fruits. It is particularly necessary to fruit and root crops. It is also found in the juices of plants which are somewhat acid, where it neutralizes a part of such acids—as, citric, tartaric, and oxalic—by forming the salts of these acids. Potassium forms a large per cent. of the wood of fruit-trees.

Beg 5th wk.

## *C.*—FERTILITY OF THE SOIL.

A fertile soil "contains all the material requisite for the nutrition of plants in the required quantity and in the proper form." That is, all the materials for the nutrition of plants not derived from the air are contained in a fertile soil.

One must know whether the food elements

of the desired crop are present in the soil. This question can be answered by chemical analyses of plants and of soils.

**I. Chemical Analysis of Soils.**

If the required elements for a certain crop are not present in the soil they must be supplied by a fertilizer, or some other crop sown.

But if chemical analysis does show the necessary elements to be present, it does not satisfactorily answer the question as to whether that food is *available* for the use of the plant; that is, whether conditions are such that the plant can and will use this food.

As has already been shown, the chemical composition of the rock from which the soil is obtained, the texture, drainage, temperature, tillage, ventilation, and water content of the soil—which determine the delicate and little-understood life processes of the plant—all are factors in the productiveness of the soil.

There are so many conditions, then, that enter into the productiveness of the soil which chemical analysis cannot take into account that it is generally of little practical use to the farmer.

**II. Vegetation Experiments.**

These are of much value in determining just what fertilizer is needed, but they require time. If, however, the farmer will do as the United States Department of Agriculture advises,

"make his farm an experiment station," he can solve these problems from year to year without much loss of time and land, and with great profit.

The food elements most apt to be lacking in ordinary soils are nitrogen, phosphorus, and potassium. The appearance of the plants (see page 80) often indicates their specific needs. But one may find out more definitely by applying one kind of fertilizer—as, sulphate of potash—to one plot of a field, and another kind of fertilizer—as, sodium nitrate or superphosphate of lime—to another plot, and a complete fertilizer, or mixture of the three (see page 94), upon a third plot, and comparing results carefully. The next year the whole field may be treated with the particular fertilizer which the results of these experiments show is needed. If other conditions are right a heavy yield may be expected. These experiments may show the need of one or of all three of the fertilizers—nitrate, phosphate, or potash; or it may be that none of them increase the yield, when one must look to other conditions of soil, or plant, to solve the difficulty.

Fri.
1. Fri.

### III. Fertilization of the Soil.

Thurs.

1. *Commercial Fertilizers.*

(1) NITROGENOUS COMPOUNDS.—The nitrogenous compounds used as commercial fertilizers

are obtained from animal, mineral, and vegetable sources, but the *source* of fertilizers has nothing whatever to do with their value as such. The value depends upon the form in which a fertilizer contains the particular plant-food desired. The nitrogen, if wanted for the immediate use of the plant, is best in the form of a nitrate, since it is soluble, and may be better distributed through the soil to the feeding roots, and is readily taken up by them.

Ammonia is the next nitrogeneous plant-food in order as regards availability. Some plants can use ammonium salts, which are soluble in water, and thus are easily distributed throughout the soil to the roots. As a rule, however, the salts of ammonia are changed into nitrates (see "Nitrifying Bacteria"), which is done very rapidly in the soil before being used by plants.

*Animal or vegetable products* cannot furnish available nitrogen to plants until decomposition takes place; hence the more rapid the decay of an organic fertilizer the more readily available is its nitrogen, since it must first be converted into ammonia and then into nitrates. (See "Nitrifying Bacteria.")

Among the fertilizers of *animal* origin, which are largely used on account of their rapid decay and comparative inexpensiveness, are: dried blood, dried meat and fish, hoof-meal, and guano. Others—as, wool, hair, and leather—decay more

slowly, and hence the nitrogen is very slowly available.

One of the best *vegetable* nitrogenous fertilizers is cottonseed-meal. It is largely used in the South, but its usefulness as a food for cattle makes it too expensive, in many cases, for a fertilizer. Castor pomace, obtained as a waste product in extracting the oil from the castor bean, is of no value as a food, and decays rapidly in the soil, hence makes a useful and inexpensive fertilizer, though it contains only about one-half as great a per cent. of nitrogen as chemically pure sodium nitrate.

Mineral Sources.—Soluble nitrate is commonly obtained as nitrate of soda, or "Chile saltpeter," which is found in deposits in the rainless regions of the Peruvian coast. It contains a large per cent. of common salt, but when purified, as prepared for commerce, it is 95 per cent., or more, pure sodium nitrate ($NaNO_3$), and about 15 or 16 per cent. of this is nitrogen.

Sulphate of ammonia, $(NH_4)_2SO_4$, is formed from coal as waste material in the manufacture of gas and coke, also from the dry distillation of animal bone in the making of bone-black. It generally contains about 20 per cent. of nitrogen, making it the richest in nitrogen of any of the commercial fertilizers. It is quick to act, and is readily distributed in the soil, and,

considering its concentrated form, is comparatively inexpensive.

(2) PHOSPHOROUS COMPOUNDS. — The compounds of phosphorus with lime, magnesia, iron, and alumina are widely distributed in the soils, but they are insoluble in water, and hence are so slowly available as to be insufficient to furnish the necessary supply for repeated crops.

Apatite

Phosphate of lime is the compound used most in the manufacture of commercial fertilizers. The mineral or rock calcium phosphate, or animal phosphates—as, bone-black and bone-ash, or animal bone—is treated with sulphuric acid ($H_2SO_4$), in order to render the insoluble tri-calcium phosphate, $Ca_3(PO_4)_2$, soluble. The soluble phosphate made from the bone-black or bone ash is best, because more of the phosphate may be converted into a soluble form. It makes a fine, dry, easily handled fertilizer. The insoluble, or tri-calcium phosphate, is treated with sulphuric acid, and a large per cent. of it is rendered soluble by two parts of the lime uniting with the sulphuric acid to form gypsum ($2CaSO_4$). This mixture of gypsum * and the soluble phosphate (mono-calcium phosphate) is sold as a fertilizer under the name of superphosphate of lime. It is probable also that some of the tri-calcium phosphate loses only one part of the lime and becomes di-calcium

* Remsen's *Inorganic Chemistry*, p. 328.

phosphate, which is not soluble in pure water, but is soluble in the acid soil waters and the acids exuded by the rootlets, and is, therefore, available to plants. So that the mono-calcium and di-calcium phosphates contained in a commercial fertilizer together are called the "available phosphoric acid" (see Table). Mono-calcium phosphate is immediately available to plants, and will give quick returns; but that which remains in the soil changes to the di-calcium, or reverted form, which is precipitated as a fine powder, and is easily dissolved through the acid reaction of the roots.

The supply for manufacturing these fertilizers comes largely from South Carolina, which has, perhaps, the richest deposits of rock phosphates in the world. Other valuable deposits are found in Florida, consisting not only of phosphates of lime, but also of phosphates of iron and alumina. Still others are found in Tennessee, Pennsylvania, and Virginia.

Bone-black is obtained by heating animal bones in the absence of air, when the gases and oily matters are driven off, and charred bone or bone charcoal is left. This is used for refining sugar; when it is of no further use for this purpose it is sold as a fertilizer. In this form, however, it is slowly soluble, and of little practical value. When bone-black is treated with sulphuric acid a much greater per cent. of sol-

uble phosphate is found than when the mineral, or rock phosphate, is thus treated. In this form it is called "dissolved bone-black," and is a valuable fertilizer.

Other commercial fertilizers containing phosphorus, with their comparative values, are given in the table.

(3) Potassium Compounds.—The potassium in the soil is largely in the form of insoluble silicates. The potassium salts of mineral origin used as commercial fertilizers are nearly all obtained from German mines; those most common are the sulphate, muriate, and kainit—a mixture of several salts, as sodium, potassium, and magnesium sulphates and muriates. All of these are available for the use of the plant, since they are soluble in water. Pure potassium sulphate contains about 54 per cent. of potassium oxide, but the composition of the commercial article varies, some grades containing not more than 30 per cent. The muriate of potassium ($KCl$) of commerce contains about 52 per cent. of potassium.

Ashes resulting from burning wood, cottonseed hulls, and tobacco stems contain from 5 to 30 per cent. of potassium carbonate. The amount of potassium carbonate ($K_2CO_3$) in ashes depends upon the kind and quality of the wood, the intensity of the heat in burning, and their protection from moisture. Ashes also contain

from 1 to 4 per cent. of phosphates, and from 30 to 40 per cent. of calcium carbonate. Good wood ashes not only furnish available plant-food, but improve the physical condition of the soil. Coal ashes are of no use as a fertilizer.

(4) **TABLE I.**

SHOWING THE COMPOSITION OF SOME OF THE PRINCIPAL COMMERCIAL FERTILIZING MATERIALS.*

| CONSTITUENT. | *Nitrogen.* | *Available Phosphoric Acid.* | *Insoluble Phosphoric Acid.* | *Total Phosphoric Acid.* | *Potash.* | *Chlorine.* |
|---|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 1. *Supplying Nitrogen.* | | | | | | |
| Nitrate of soda . . . . . | 15.5–16 | . . . . | . . . . | . . . . | . . . . . | . . . . |
| Sulphate of ammonia . . | 19.0–20.5 | . . . . | . . . . | . . . . | . . . . . | . . . . |
| Dried blood (high grade) . | 12.0–14 | . . . . | . . . . | . . . . | . . . . . | . . . . |
| Dried blood (low grade) . | 10.0–11 | . . . . | . . . . | 3–5 | . . . . . | . . . . |
| Castor pomace . . . . . . | 5.0–6 | . . . . | . . . . | . . . . | . . . . . | . . . . |
| 2. *Supplying Phosphoric Acid.* | | | | | | |
| Bone-black superphosphate (dissolved bone-black). . . . . . . . . . | . . . . . | 15–17 | 1– 2 | 17–18 | . . . . . | . . . . |
| Ground bone . . . . . . . | 2.5– 4.5 | 5– 8 | 15–17 | 20–25 | . . . . . | . . . . |
| Steamed bone. . . . . . . | 1.5– 2.5 | 6– 9 | 16–20 | 22–29 | . . . . . | . . . . |
| Dissolved bone . . . . . . | 2.0– 3 | 13–15 | 2– 3 | 15–17 | . . . . . | . . . . |
| 3. *Supplying Potash* | | | | | | |
| Muriate of potash . . . . | . . . . . | . . . . | . . . . | . . . . | 50 | 45–48 |
| Sulphate of potash (high grade) . . . . . . . . . | . . . . . | . . . . | . . . . | . . . . | 48–52 | .5–1.5 |
| Kainit. . . . . . . . . . . | . . . . . | . . . . | . . . . | . . . . | 12–12.5 | 30–32 |
| Wood ashes (unleached) . | . . . . . | . . . . | . . . . | 1–2 | 2–8 | . . . . |
| Wood ashes (leached) . . | . . . . . | . . . . | . . . . | 1–1.5 | 1–2 | . . . . |
| Tobacco stems . . . . . . | 2.0– 3 | . . . . | . . . . | 3–5 | 5–8 | . . . . |

The above table shows the comparative values of the most important commercial fertilizers as food for plants. The amount of these

* Adapted from *Year-book*, 1902, p. 571.

fertilizers required varies upon different soils and for different plants.*

The smallest amounts of direct fertilizers to the acre, which will give satisfactory returns, are 10 pounds of nitrogen, 15 pounds of available phosphoric acid, and 20 pounds of potash. By comparison with the above table the amount of the *commercial fertilizer* required may be obtained.

EXERCISE 3.—How much nitrate of soda will be needed for an acre if 10 pounds of nitrogen be required? (See Table I.)

How much sulphate of ammonia?

How much dried blood (high grade)?

How much castor pomace?

How many pounds of phosphoric acid and of potash in castor pomace which furnishes 10 pounds of nitrogen?

How many pounds of bone-black superphosphate will it take to furnish 15 pounds of *available* phosphoric acid? How many pounds of nitrogen will this bone-black contain? How many pounds of insoluble phosphoric acid?

How many pounds of sulphate of potash will it take to furnish 20 pounds of potash? How much kainit? How much (unleached) wood ashes? How much phosphoric acid contained in this sulphate of potash? How much in the wood ashes?

For indoor plants, again, the amount of the fertilizer must be governed by the kind of soil and species of plant, for what is a "balanced ration" ‡ for one kind of plant is not for another.

* "It is unsafe to use chemical fertilizers or liquid manures in full strength on a heavy soil, which is not provided with sufficient fibrous material."—*Year-book*, 1902, p. 558.

The following estimate * may be helpful, but *practical experience is the only safe guide* as to which plant-food, and how much is needed:
(3) Nitrate of soda, 6 to 10 ounces, in 50 gallons of water to 100 square feet ;† sulphate, or muriate, of potash, 8 to 12 ounces in 50 gallons of water to 100 square feet, or wood ashes, 5 pounds to 100 square feet; calcium superphosphate, 11 pounds in 50 gallons of water to 100 square feet. Whichever fertilizer is needed should be used every ten days, or two weeks, in watering the plants.

For mixed, or so-called "complete fertilizer," Voorhees‖ recommends one-fourth pound of nitrate of soda, one pound acid phosphate, and
(4) one-half pound of muriate of potash for 100 feet. But some think this a little too much. (See also "Plant Improvement.")

The *kind* of fertilizer, as to its slow or rapid availability, to be used depends upon whether the object desired is to slightly enrich the soil
(5) for a period of years or to increase the yield of the immediate crop.

The *time* of application would depend upon
(6). the kind of fertilizer and the object of its use.

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* This estimate was given for roses in the *Year-book*, 1902, and is meant only as an example.

† "After the second or third application, a light dressing—5 lbs. to 100 square feet—may follow."—*Year-book*, 1902, p. 557.

‖ *Fertilizers*, by Voorhees, p. 327.

If wanted for the immediate use of the plant, it must necessarily be soluble, and, consequently, should not be applied in the fall but in the spring, when the crop is ready to use it, else it will be leached away and lost. If the more slowly available ones are used, they should be applied in the fall.

*How Applied.*—Fertilizers must be evenly and thoroughly distributed in the soil. For this reason it is well to mix concentrated fertilizers with dust, ashes, or sand. They may then be (7) scattered broadcast, and plowed or harrowed in, or drilled in. Those which are readily soluble may be simply distributed over the surface, as the rains will carry them into the soil.

*When should commercial fertilizers be used?* Not until *all home resources are exhausted* should a farmer buy fertilizers. Proper preparation of the soil by drainage and tillage, attention to rotation of crops, taking care that leguminous (8) plants constitute at least one crop in four, so that particular elements will not be exhausted by continuous drain upon them, will do much toward keeping up the yield afforded by the soil. But this is not enough; all must not be taken out and nothing put in. However, if all waste products on the farm are utilized, there will be little need of expending much money for commercial fertilizers.

(5) LIME.—Plants need lime. It tends to (9)

make them more compact, and aids in the production of grain or fruit. Especially is it helpful to leguminous plants, grains, and grasses; but it is of much less value to corn, and may be even injurious to potatoes, blackberries, redtop, and millet. Lime neutralizes part of the acid in plants forming salts, as the calcium oxalate of beet leaves; but its most important action is that of an *indirect fertilizer*. It benefits the soil as to its physical condition, tending to make clayey soils more porous and light, and sandy soils more compact.

Lime changes the chemical constituents of the soil. It is in this action that it brings an increased yield to the immediate crop; for by chemical action upon organic matter, hastening its decomposition, and upon the insoluble potassium and phosphorus compounds in the soil, it renders them available to the plant. While this would tend to produce heavier crops, the continued use of lime, or gypsum, would help to exhaust the soil of its natural plant-food by the increased drain made upon it through the greater yield.

Lime neutralizes the acidity of the soil. Through root-action of some plants, or through the formation of acids by the decomposition of organic matter and consequent formation of humous and humic acids, or through the excessive use of fertilizers, or by leaching, the soil

may become so strongly acid in its character as to be unfavorable or unproductive to certain valuable species of plants. This condition may exist not only on swampy or peaty soils, but also upon well-drained soils. Soil may be easily tested for acid by thoroughly moistening it and placing in it a strip of blue litmus paper. If the color of the litmus paper is changed to red the acid of the soil is too strong for plant growth, and the addition of lime will prove beneficial.

Another way in which the need of lime in a soil in shown is by the plants which it will naturally produce. Plants known to be characteristic of acid soils are: bird's-foot violet (*Viola pedata*), wild or beard grass (*Andropogon scoparius*), wood-rush (*Luzula campestris*), and, as soon as the soil is cultivated, the common sorrel (*Rumex acetosella*), while those plants which are unable to make any satisfactory growth upon such soils are the red clover, lettuce, beets, timothy, and spinach.* omit.

EXERCISE 4.—(*a*) Collect small samples of soil from various places where the vegetation might lead one to suspect the presence of acid soil. 3

(*b*) These samples of soil should be taken from about two to four inches below the surface, and each sample carefully labeled as to exact location from which it was obtained. 4

(*c*) These samples should be taken to the laboratory, 5

* Roberts' *Fertility of the Soil*, p. 318.

and tested for acid w'th blue litmus paper. If need be, leave the litmus paper covered in the soil over night.

(*d*) If any soils turn the litmus paper red, the class should visit that particular place, or places, where the acid soils were found, and study the vegetation, making a list of the plants found growing there, and examine the conditions, to discover, if possible, the cause of the acidity. Is the drainage good? The ventilation? Is the place densely shaded? What is the texture of the soil? Is it a humous, loamy, clayey, or sandy soil? Could the conditions be improved? How?

(*e*) Collect a sufficient quantity to fill several small pots with this soil, and try to grow some plant which is averse to acid soil—as, clover, lettuce, or timothy. To one pot add lime in small but definite quantities, thoroughly mix, and let stand for a few days. Test again with litmus; if still acid, add lime until the litmus is no longer affected, and then try to grow the same kind of a plant as in the pot of acid soil, starting them both at the same time and keeping them under similar conditions.

(*f*) Compare the growth made by the two plants, and record your observations and conclusions.

Not only does lime sometimes prove beneficial to plant growth, but it is also beneficial to the development of the nitrifying bacteria of the soil, which for some reason thrive best in a mildly alkaline soil (see "Clover Sick Soil.") Lime and wood ashes aid nitrification by furnishing calcium and potassium to unite with the nitric acid formed by the bacteria. Lime is also helpful in keeping in check certain injurious insects and fungi, though the potato scab (a fun-

gous growth) seems to develop more rapidly when this crop is preceded by liming.

One form of calcium—the sulphate, called land plaster or gypsum—fixes ammonia, while lime drives it off. Hence this is exceedingly useful for sprinkling in the trenches of stables, or upon the surface of compost heaps, to prevent the escape of the ammonia. For use in connection with manure, no other form but the sulphate (gypsum) should be used. It is also best for an indirect fertilizer—that is, for rendering the present but unavailable plant-food available.

For neutralizing acids, calcium oxide (CaO), or quicklime, is the best form to use. It must be slaked a short time before using. It may be placed in heaps and water sprinkled over it, and then covered with soil for a few days. It should be free from lumps, spread or drilled evenly, and harrowed in at once. This form is also a cheap and very good indirect fertilizer.

Another method of indirect fertilizing is by the judicious use of cover crops (see "Leguminous Plants" and "Rotation of Crops"). Plant roots not only make mineral plant-foods more easily available, but prevent them from being leached out by the winter rains and snows. (10)

2. *Stable Compost.*

As has been said, green manuring is expensive, since the crop may be fed to stock, and if the stable compost is properly cared for and returned

to the soil a large per cent. of the important food elements taken up from the soil by the plants will be restored to the soil. For it must be remembered that this compost not only contains the indigestible food elements, but also the broken-down or worn out animal tissues.

(1) VALUE IN FURNISHING PLANT-FOOD.—The amount and kind of the elements of plant-food found in stable compost depend upon the kind of food* fed to stock, and the age and kind of stock to which it is fed, and the care taken of the compost. Mature animals (except milch cows) return, sooner or later, nearly all of the fertilizing† elements of the food in the waste discharged, while only one-half or two-thirds is returned by young and rapidly growing animals. Fattening cattle return from 85 to 90 per cent.

Roberts estimates the commercial value of the fertilizing materials found in the compost of different farm animals as varying from $2.43 to $4.25 per ton, rating the nitrogen contained at 15 cents, phosphoric acid at 7½ cents, and potash at 4½ cents per pound. He also states that in many cases the "computed value of the waste is nearly one-half the cost of the food"; but adds, "this value can seldom be realized when

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* See Table, p. 134.

† Henry's *Feeds and Feeding*, p. 270.

the compost is applied to the land."* However, if the real value reaches one-half of the computed value it is of too great value to be thrown away.

(2) SHAMEFUL WASTE.—The way in which this valuable fertilizer is allowed to stand exposed to the weather, allowing by far the most valuable elements of plant-food to be leached out and drained away down the hillside, only to pollute the water accessible to the stock or to contaminate the air, and to serve as a breeding-place for flies and disease germs, is shameful waste if not criminal carelessness.

Many farmers allow this fertilizer to be hauled away to increase the yield of the crops of a more thrifty neighbor, or even burn it to get it out of the way. And this in the face of the fact that there is no more vital problem in the world to-day than that of maintaining or improving the fertility of the soil. As population increases this question assumes momentous importance. Already in the "old world" it is found that the soil is not able to supply a subsistence for the population. All the food, clothing, and shelter for all animals, including man, must come directly or indirectly from the soil. When this soil is exhausted through the carelessness of man, where will this same man appease his hunger or obtain a sustenance?

* Roberts' *Fertility of the Land*, p. 143.

(3) Effects Upon the Soil.—Stable compost not only enriches the soil by supplying plant-food (being especially rich in nitrogenous compounds), but it very materially improves the physical condition of the soil. It changes the potash, phosphate, and lime present in the soil into more readily available forms, and favors the development of the nitrifying bacteria. The effects of stable compost are more lasting than those of any other fertilizer on account of its uniting with the elements of the soil to form humates, which are changed to available forms by the nitrifying bacteria. The liquid in stable compost contains valuable plant-food in a soluble form; hence, free use of bedding should be made to absorb and retain these liquids. A mixture of dried muck‡ and marl‡ (when easily obtained) makes a good absorbent, and will prove beneficial to a sandy soil. Gypsum is valuable in fixing the ammonia contained in these liquids, and should be sprinkled in the trenches or over the compost heaps for this purpose.

(4) Protection and Application of the Compost.—Covered barn-yards (Fig. 29) prevent the loss of the compost by scattering and leaching,* at the same time affording warmer quarters for the stock in winter and cooler in summer.

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* Roberts' *Fertility of the Soil.*

Some successful farmers advocate the removal of the compost from the stable directly to the field. Others place it in covered heaps, or bins, and sprinkle with gypsum. Fresh compost acts injuriously with some crops.*

Fairly well-rotted manure may be harrowed

FIG. 29.—A COVERED BARN-YARD.

in in the fall or late summer, but if sufficiently rotted to be available, it may be applied in the spring.

Plants may be overfed as well as underfed,

* *Year-book*, 1901, p. 171.

so frequent, light applications are better than heavy ones at long intervals.*

It would be well to occasionally add to every ton of compost applied to the soil from fifty to one hundred pounds of superphosphate, and twenty-five to fifty pounds of sulphate of potash (high grade), or sufficient wood ashes to supply the same amount of potash (see Table I.).

For potted plants, or in soil used for vegetables or flowers, the water leached from stable compost and diluted may be used (see page 256) in watering the plants to supply the fertilizer.

One ton of stable compost in good condition contains about ten pounds of nitrogen, five pounds of phosphoric acid, and ten pounds of potassium.

## *D.*—REFERENCES.

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* "We may take it as a general rule that plants with leathery leaves, with hard and narrow leaves, and with hard wood, require more dilute solutions than those with large, soft, and expanded leaves. During the period of leaf formation all plants can do with the greatest amount of nutritive matter."—*Yearbook*, 1901, p. 172.

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Rock Phosphate

3-5 Mon. Oral review-

4 Tues. Oral Review.

exhausted in 50 years-

3- Tues. Written Test.

4-5 Wed. Written Test.

Chloride -

# OUTLINE OF CHAPTER V.

## LEGUMINOUS PLANTS.

### *A.*—LEGUMINOUS PLANTS AS NITROGEN GATHERERS.

**I. Nitrogen-fixing Bacteria.**
**II. Inoculation of the Soil.**
**III. Other Conditions.**

### *B.*—LEGUMINOUS PLANTS AS SOIL RENOVATORS.

**I. As Deep Feeders.**
1. *Mechanical Action.*
2. *Chemical Action.*

**II. For Green Manuring.**

### *C.*—LEGUMINOUS PLANTS AS FOOD.

**I. High per cent. of Digestible Crude Protein.**
**II. Table of Comparisons.**
**III. Not Lacking in Carbohydrates.**

### *D.*—SPECIFIC CASES.

**I. Red Clover.**
**II. Crimson Clover.**
**III. Alfalfa.**
**IV. Cow-peas.**
**V. Soy-beans.**

### *E.*—REFERENCES.

# CHAPTER V.

## LEGUMINOUS PLANTS.

From the foregoing chapters the student should have an understanding of the fact that the food of plants must contain certain elements, and that these food elements must be obtained from the air or as soluble material from the soil, so that they can be absorbed by the roots.

One of the most important elements is nitrogen (see Chapter IV.). It is found in the protoplasm of every plant cell. The nitrogenous compounds in the plant, taken as a whole, are called crude protein. No plant can live without a supply of nitrogenous food.

Now if this nitrogen is to be obtained from the soil, and since the plant requires so great a proportion of it, it will be easily seen that the supply in ordinary soils would in time be exhausted unless some means were taken to replenish it. This is usually done by the application of a fertilizer—some salt of nitrogen, which is the most expensive of fertilizers.

## *A.*—LEGUMINOUS PLANTS AS NITROGEN GATHERERS.

### I. Nitrogen-fixing Bacteria.

1888 In recent years it has been discovered (see foot-note, p. 32) that certain plants, through their intimate relation with other low plant forms, bacteria, are able to obtain nitrogen from the inexhaustible supply of the air. The exact relation existing between these soil bacteria and the roots of leguminous plants is not fully understood. But it has been proven by many experiments that wherever the bacteria which work upon a particular species of plant are present—which is shown by the nodules upon the roots (Fig. 31)—the plant is able to make a luxuriant growth without the addition of nitrogenous fertilizers, providing, of course, that other necessary conditions are present.

### II. Inoculation of the Soil.

It sometimes happens that the particular species of bacteria which works upon a certain species of leguminous plant is not present in the soil. In this case the plant—vetch, for example—has no nodules upon its roots (Fig. 30), is weak and sickly, and a profitable crop cannot be obtained unless heavy applications of nitrogenous fertilizers are made, which would entail considerable expense, or the soil of this field be inoculated with the bacteria which work

FIG. 30.—COMPARISON OF VETCH PLANTS.
Grown upon inoculated and uninoculated soil.

upon this vetch. This inoculation may be done by a light application of the soil in which these bacteria are known to be. Their presence is indicated by the luxuriant growth of the vetch

FIG. 31.—ROOTS OF YELLOW SOY-BEAN.

Grown at the Kansas Agricultural Experiment Station in 1896, on land inoculated with an extract containing the tubercle-forming bacteria.

and the presence of nodules on its roots (see Fig. 30). If any considerable area is to be inoculated, this method of inoculation is too expensive to be practical, as it requires from 500 to 1,000 pounds of soil to an acre.

Recently, through investigations in the labo-

ratory of Plant Physiology, the Department of Agriculture at Washington has shown that "the bacteria, when grown upon nitrogen-free media, will retain their high activity if they are carefully dried out and then revived in a liquid medium at the end of varying lengths of time. By using some absorbent which will soak up millions of the tubercle-forming organisms, and then by allowing these cultures to become dry, the bacteria can be sent to any part of the United States or the world, and yet arrive in perfect condition. Of course, it is necessary to revive the dry germs by immersion in water, and, with the addition of certain nutrient salts, the original number of bacteria is greatly increased if allowed to stand for a short time. Frequently twenty-four hours are sufficient to cause the water in a pail to turn milky white with the number of organisms formed in that time. Thus, by sending out a dry culture similar to a yeast cake, and no larger in size, the original number of nitrogen-fixing bacteria may be multiplied sufficiently to inoculate at least an acre of land. The amount of material thus obtained is limited only by the quantity of the nutrient water solution used in increasing the germs. It is evident, therefore, that the cost of inoculating the land is very small." The dry cultures may be obtained from the United States Department of Agriculture without cost.

"The way in which the liquid culture may be introduced into the soil varies somewhat with the character of the seed to be used and the area of the field to be treated. With large seed it is often more convenient to simply soak them in the fluid, or moisten them with it, and then, after they are sufficiently dry, to sow them in the ordinary way. In other cases it is frequently more feasible to introduce the liquid culture directly into the soil. This may be done by spraying, or perhaps a simpler method is to mix the culture thoroughly with a wagon-load of earth, and then to distribute and harrow this in, just as a fertilizer would be handled." *

**III. Other Conditions.**

It may be possible that some condition of the soil prevents the healthy growth of the species of bacteria. They require an abundant supply of air (see "Tillage") and plenty of moisture, though this should not be present in sufficient quantities to prevent the free circulation of the air. They will not thrive in an acid soil; hence, if difficulty is found in growing leguminous crops, it would be well to give the soil a light application of lime if it is not known to already contain it.

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* *Year-book*, United States Department of Agriculture, 1902, p. 341.

## *B.*—LEGUMINOUS PLANTS AS SOIL RENOVATORS.

### I. As Deep Feeders.

Leguminous plants also have the advantage of being deep feeders; hence, they require a subsoil which they can penetrate, and alfalfa, in particular, cannot be successfully grown if the soil is underlaid with rock or hard-pan.

The roots of these plants thus improve the soil in two ways:

1. By *Mechanical Action* they loosen the subsoil, making it more easily penetrated by water, and by subsequently formed roots; and,

2. *Chemically*, by bringing up from below quantities of the salts of phosphorus and potassium, as well as obtaining, through the bacteria, a rich supply of nitrogen from the air. Large amounts of these elements, by the decay of these roots and the stubble, are prepared for the use of subsequent crops of surface-feeding plants.

FIG. 32.
ALFALFA PLANT.
Long root-system.

**II. For Green Manuring,**
or plowing under for fertilizing, the leguminous plants, such as the red, white, or the crimson clover, cow-peas, and soy-beans, are of more value than other crops, since they are comparatively rich in phosphorus and potash, and furnish a supply of nitrogenous compounds, the nitrogen of which is obtained, through their relation with certain bacteria, from the air, thus not impoverishing the soil. Green manuring with leguminous plants, while very effective, can hardly be afforded, except for the purpose of building up worn-out, or poor, soil, since leguminous hay is so valuable as feed (Chapter I.). At the same time more than half of the fertilizing elements may be given back to the soil in manure if rightly taken care of and applied.

## *C.*—LEGUMINOUS PLANTS AS FOOD.

**I. Digestible Crude Protein**
is absolutely essential to the upbuilding of the tissues of the animal body in repairing broken-down tissues. It has been proven by repeated experiments that a ration which contains a large per cent. of digestible crude protein gives the best results for the least money in the production of milk, and in contributing to a vigorous and healthful growth of the young. It has been ascertained by analysis, as shown by the following table of comparisons, that the per cent. of

protein contained in the hay of leguminous plants is more than double that in the same weight of the hay of grasses.

**II.—TABLE OF COMPARISONS.***

DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS.

| NAME OF FEED. | *Dry Matter in 100 Pounds.* | DIGESTIBLE NUTRIENTS IN 100 POUNDS. | | | FERTILIZING CONSTITUENTS IN 1,000 POUNDS. | | |
|---|---|---|---|---|---|---|---|
| | | *Protein.* | *Carbohydrates.* | *Ether Extract.* | *Nitrogen.* | *Phosphoric Acid.* | *Potash.* |
| *Hay* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* |
| Timothy . . . . . | 86.8 | 2.8 | 43.4 | 1.4 | 12.6 | 5.3 | 9.0 |
| Redtop . . . . . . . . | 91.1 | 4 8 | 46.9 | 1.0 | 11.5 | 3.6 | 10.2 |
| Kentucky blue-grass | 78.8 | 4.8 | 37.3 | 2.0 | 11.9 | 4.0 | 15 7 |
| Red clover, medium. | 84 7 | 6.8 | 35 8 | 1.7 | 20.7 | 3.8 | 22.0 |
| White clover . . . . | 90.3 | 11 5 | 42.2 | 1.5 | 27.5 | 5.2 | 18.1 |
| Crimson clover . . . | 90.4 | 10.5 | 34.9 | 1.2 | 20.5 | 4.0 | 13.1 |
| Alfalfa . . . . . . . | 91.6 | 11.0 | 39.6 | 1.2 | 21.9 | 5.1 | 16.8 |
| Cow-pea. . . . . . . | 89 3 | 10.8 | 38.6 | 1.1 | 19.5 | 5.2 | 14.7 |

When it is considered that the majority of leguminous plants yield two or more crops annually, it will be seen that they supply from two to four times as much protein per acre as the grasses. Of the nitrogen contained in this protein, it should again be emphasized that a large proportion of it is obtained from the air, through the relation of these plants with the bacteria, and thus the soil is not deprived of its supply of nitrogen, as is the case with other forage plants; hence, no expensive nitrogenous fertilizer will be required to replenish the soil of fields sown with leguminous crops.

* Adapted from Henry's *Feeds and Feeding.*

### III. Not Lacking in Carbohydrates.

It will also be seen from the table that the leguminous hay only lacks about 5 per cent. of being as rich in the heat-producing elements, carbohydrates and ether extract, as the hay of grasses. On the other hand, it will require in most cases no supplementary nitrogenous food in the form of expensive meals as wheat shorts, gluten meal, and cottonseed-meal, as does the hay of grasses.

*Leguminous plants are valuable*, then, in that (1) they do not exhaust the soil of its nitrogen, but may be made (through their relation with the bacteria) to add to the soil's supply of nitrogen from that of the air; (2) they are deep feeders, and bring up from below and deposit near the surface other kinds of plant-food; (3) they make a more economical food than grasses; (4) that the manure from such crops makes a better fertilizer than that obtained by feeding the hay of grasses.

(Omit till later)

## *D.*—SPECIFIC CASES.

### I. Red Clover (*Trifolium pratense*)

need only be mentioned, as it is already well known and its value recognized. It is widely grown in the Northern and Eastern States, but is not generally grown so successfully in the South and West as other legumes. It is best to cut it when not more than 20 per cent. of the

blossoms are turning brown, since not only is the yield heavier at this time (as the leaves, which are the best part of the hay drop off when it is riper), but its nutritive value is greatest.

Clover hay is excellent *roughage* for sheep, cows, and growing stock. The dust detracts from its value as roughage for horses, but a limited amount may be fed to them in connection with other rough food.

**II. Crimson Clover** (*Trifolium incarnatum*), though not so valuable for hay as red clover—since it is an annual and makes but one crop—is excellent for green manuring, winter soil mulching, and *soiling*—cutting green and supplying to the stock in barns and yards.

It is better adapted to the Southern States, as the fall sowing will not stand the severe winters of the North, nor the drouth of the western plains, though fine crops have sometimes been obtained outside the Southern States.

It may be sown in spring or early summer, when it matures in late summer or autumn. This crop makes a good fall pasture, after which it may be plowed under, or if not having been allowed to produce seed and it survives the winter, it may be used for green food, soiling, or as green manuring in the spring. It is, however, commonly sown in late summer or early fall; where the winters are mild it serves excellently as a winter soil mulch.

In the spring it may be used as green manuring for corn or cotton fields, or for soiling or spring pastures, or it may be allowed to grow for hay; but *it must be cut before it is in full bloom*, for when the blossoms are fully ripe the bristly hairs and the calyx are liable to form balls in the stomach or intestines of horses or cattle, which cause their death.

**III. Alfalfa** (*Medicago sativa*).

Alfalfa cannot be grown on all soils. It is a deep feeder, the roots penetrating the ground to a depth of from eight to twenty-five feet (Fig. 32), and cases have been reported where, in loose sandy soils, alfalfa roots have been found at a depth of from fifty to sixty feet.

It must have a subsoil which its roots can penetrate. The soil must be well drained and well ventilated, so that the nitrogen-fixing organisms (bacteria) which work upon its roots may be well supplied with nitrogen from the air. It thrives best in a soil rich in lime, potash, magnesium, and phosphorus—lime being the most essential.

The soil must be thoroughly prepared. A field should be selected which is free from the seeds of weeds, and plowed thoroughly and deeply. If no subsoil plow is to be had, "the best substitute is two turning plows, the one following in the furrow made by the other." It must then be thoroughly pulverized and made

smooth. This prepares the ground, for from four to forty years, for three to five crops per year, so the work may well be done with care.

As soon as there is no more danger of frost in the spring the alfalfa seed—which has been screened to allow, if present, the fine seeds of its worst enemy, the dodder, to pass through (see "Purity of Seeds," Chapter IX)—should be drilled in thickly (20 to 25 pounds to the acre) to keep down the weeds. The field may be enriched occasionally with fertilizers containing lime, potash, and phosphoric acid, but no nitrogenous fertilizer will be needed.

The stable compost, when feeding alfalfa, makes an excellent fertilizer for surface-feeding crops, as the grasses and grains.

The weeds should be carefully kept down by reseeding the spots where the stand is poor, and by frequent mowing, if need be, until the alfalfa has reached the third year of its growth, when the root system will have become strongly developed and a good stand may be expected.

Of all the leguminous plants, alfalfa seems to have the greatest number of points in its favor. It enriches the soil by bringing up from great depths plant-food, and depositing it in its tissues near and upon the surface. It, in connection with the infesting bacteria, gets its supply of nitrogen from the air, and stores up large quantities of nitrogenous compounds in its tis-

sues. It makes excellent pasture for horses and hogs; however, it will not bear too close feeding, as it does not sprout from the stem but from the roots, and the "vitality of the root may be impaired if the young stems are grazed as fast as they appear." Alfalfa is not a good *green* food for cattle and sheep, as it causes them to bloat, though it is believed by some that if a supply of dry roughage is put where they can get it while feeding on alfalfa and clover pasture, that stock will not suffer from bloating.* Soiling (see "Principles of Feeding") also may be practiced with alfalfa. There is no farm crop of greater value as hay. Alfalfa hay is richer in digestible nutrients than red clover hay, and from three to five, or as many as seven, cuttings may be made from an alfalfa field annually. It should be cut for hay when it first begins to bloom. Alfalfa hay should be handled as little as possible to get it into the stack or barn, as the leaves, which are the best part of the hay, drop off when dry. The hay should be sheltered from rains. The second crop of alfalfa (in Colorado and similar localities the first is used) should be cut for seed, as the blossoms ripen more uniformly, and this crop seeds better—probably because there are a greater number of insects to fertilize the flowers.

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* Henry's *Feeds and Feeding*, p. 201.

Since alfalfa hay is exceedingly rich it must be supplemented by foods containing the carbohydrates—as, corn fodder, straw, or silage. Alfalfa is adapted to a wide range of latitude. It has been successfully grown as far north as Central New York, Michigan, and Montana, and as far south as California, Louisiana, and Florida, and it stands the drouth of the western plains better than any other forage crop.

**IV. Cow-peas** (*Vigna catjang*).

There are numerous varieties of cow-peas, from the "bush-pea" to the prostrate runners, with many gradations between them. Their season of growth varies from a few weeks to several months (see "Variation Induced by Environmental Changes—Climatic").

Cow-peas will grow on soil which is too poor to support clover, and they are excellent soil-renewers when plowed under green, and far less expensive than commercial fertilizers for worn-out or barren soil. This crop is best adapted to the South, as it, like that of other beans, is very sensitive to frost. Certain varieties, however, have been grown as far north as Wisconsin—also in the New England States, as soiling crops.

Much of the failure in the North has been caused by planting when the ground was too cold or wet. From the table it will be seen that the hay of cow-peas yields a greater per

FIG. 33.—THE COW-PEA.

cent. of dry matter than that of red clover. It is also much richer in the digestible protein. In the Gulf States a yield of from four to six tons per acre is common. The South Carolina Station reported, in 1889, a yield of 3.6 tons to the acre. Its analysis showed that it furnished

twice the amount of digestible nutrients as that of one acre of oats yielding forty bushels, and

FIG. 34.—THE SOY-BEAN.

40 per cent. more than that produced by an acre of corn yielding thirty bushels.

When cow-peas are grown to enrich the soil the hay may be fed to stock and the manure returned to the field, or the vines may be plowed under in the fall, and the field sown in oats, rye,

or vetch, to prevent the leaching out of valuable fertilizing materials by the rains.

The seeds make a valuable concentrated food, but since, as yet, there is no means of threshing them satisfactorily unless gathered by hand, it is quite expensive.

**V. The Soy-bean** (*Glycine hispida*) (Fig. 34) is largely grown in the South, but can be grown wherever Indian corn can be grown successfully. It feeds heavily upon potash, and requires fertilizing with lime, potash, and phosphorus if the soil is poor in these materials. It should not be planted until the ground is warm. It grows rapidly, and generally requires little cultivation.

The hay is rich in protein. It should be cut at the time of, or soon after, blooming. The seed yields from twenty-five to forty bushels per acre. The beans are rich in protein and oil, hence they make a desirable concentrated food to be fed in connection with roughage.

Omit

Exercise 5.—(*a*) Collect specimens of various leguminous plants, taking great care to procure the root systems intact.

(*b*) Look for tubercles or nodules on the roots. Where found?

(*c*) Note the relative size of nodules upon different kinds of plants, and upon the same kind of plants grown in different soils.

(*d*) Do you find any legumes which have no nodules? If so, test the soil in which they were grown for acid.

If any acid is present, what would you advise? If no acid is present, what?

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# OUTLINE OF CHAPTER VI.

## PRINCIPLES OF FEEDING.

### *A.*—OBJECT OF FEEDING.

work – milk production, meat ", labor "

### *B.*—KINDS OF FOOD.

**I. Nitrogenous Foods.** Proteids – Albuminoids.

**II. Carbonaceous Foods.** Starch, Sugar, Fats –

**III. Other Elements.**

### *C.*—COMPARISON OF NITROGENOUS AND CARBONACEOUS FOODS.

**I. Protein.**

**II. Carbohydrates.**

**III. Ether Extract.**

1. *Heat Value.*
2. *Calculating the Heat-producing Material in Corn.*

### *D.*—FEEDING TABLES.

**I. Analysis of Feeding Stuffs.**

1. *Amount of Nutrients.*
2. *Per Cent. of Digestibility.*

**II. Wolff-Lehmann Feeding Standards.**

1. *A Balanced Ration.*
2. *How the Standards were Obtained.*
3. *Standards Used Only as a Basis.*
4. *Nutritive Ratio. Exercise* 6.
5. *Compounding Rations.*

## *E.*—FEEDING STUFFS.

**I. Palatability.**

**II. Kinds.**

1. *Concentrates.*
2. *Roughage.*
    (1) Dry Forage.
    (2) Green Forage.
        (*a*) Pasture.
        (*b*) Soiling.
        (*c*) Silage.

# CHAPTER VI.

## PRINCIPLES OF FEEDING.

"*The mind of the master fattens his cattle.*"

### *A.*—OBJECT OF FEEDING.

Farm crops are grown for the *profit* there is in them to the farmer. *Farm animals* are fed to *increase this profit.*

Anything grown on the farm which will help to form a suitable food for stock should be fed and the waste returned to the soil, so that the largest profit may be obtained with the smallest loss to the soil. The profit obtained from feeding farm animals may be manifested in one of three forms of work done: (1) increase of flesh, by growth or fattening; (2) production of milk, wool, etc., or (3) labor performed.

The *amount* of digestible food, then, must exceed the supply necessary for the demands of the body by the amount sufficient to promote the *work* exacted of the animal; otherwise the work is done at the expense of the body, and the overworked and underfed animal becomes poor and weak, because it has drawn upon the tissues of the body (flesh consumption) to supply the energy for work. In the food of animals, as in that of plants, it is necessary to consider only a few kinds.

## *B.*—KINDS OF FOOD.

**I. Nitrogenous Foods.**

Those supplying nitrogenous compounds, or protein, which are used in the formation of tissues—as, muscle, bone, hair, horn, and also of blood and milk—must be furnished to promote the growth of the growing animal.

**II. Carbonaceous Foods.**

Those—as, starch and sugar—which supply the carbohydrates and fats are necessary to produce the heat and energy of the body. If there is an excess of this kind of food over that required in producing heat and energy it is stored in the body as fat, and may be drawn upon at any time when the food does not contain sufficient heat-producing elements.

**III. Other Elements.**

There are other elements necessary to a complete food, but they are always contained in sufficient quantity in all foods which supply the necessary protein, carbohydrates, and fats, so do not need to be taken into consideration in the selection of foods.

## *C.*—COMPARISON OF NITROGENOUS AND CARBONACEOUS FOODS.

**I. Protein.**

When the carbohydrates are lacking, heat and energy can be produced by the protein of the food, or even by the tissues, by flesh consump-

tion; but if *protein is lacking* in the food, neither the carbohydrates nor any other constituent can take its place. It must be borne in mind that the protein is by far the most expensive, and that it is at an actual loss to the stockman that protein-furnishing food is allowed to take the place of the cheaper carbohydrates in supplying the heat and energy of the animals fed—especially since the maintenance of heat and energy requires the greater portion of the food.

### II. Carbohydrates.

It has been found by actual experiments that when carbohydrates are fed in connection with protein that the protein consumption is lessened; hence, not only is the breaking down of the tissues of the body prevented, but more of the protein of the food is left for the formation of flesh, bone, and other tissues.

### III. Ether Extract.

The fats perform the same function in the body as do the carbohydrates. Ether extracts are the substances obtained from a "water free" food by ether. Though the terms "ether extract" and "fats" are not strictly interchangeable, they are very often so used.

1. *Heat Value.*—It has been estimated that one pound of ether extract will produce 2.4 times as much heat as one pound of carbohydrates.

## TABLE III.*

AVERAGE DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS IN AMERICAN FEEDING STUFFS.

| NAME OF FEED. | *Dry Matter in 100 Pounds.* | DIGESTIBLE NUTRIENTS IN 100 POUNDS. | | | FERTILIZING CONSTITUENTS IN 1,000 POUNDS. | | |
|---|---|---|---|---|---|---|---|
| | | *Protein.* | *Carbo-hydrates.* | *Ether Extract.* | *Nitrogen.* | *Phos-phoric Acid.* | *Potash.* |
| *Concentrates.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* |
| Corn, all analyses | 89.1 | 7.9 | 66.7 | 4.3 | 18.2 | 7.0 | 4.0 |
| Sweet Corn | 91.2 | 8.8 | 63.7 | 7.0 | 18.6 | . . . . | . . . . |
| Corn Cob | 89.3 | 0.4 | 52.5 | 0 3 | 5.0 | 0.6 | 6.0 |
| Corn and cob meal | 84.9 | 4.4 | 60 0 | 2.9 | 14.1 | 5.7 | 4.7 |
| Gluten meal | 91.8 | 25.8 | 43.3 | 11.0 | 50.3 | 3.3 | 0.5 |
| Wheat | 89.5 | 10.2 | 69.2 | 1.7 | 23.6 | 7.9 | 5.0 |
| Winter wheat bran | 87.7 | 12.3 | 37.1 | 2 6 | . . . . | . . . . | . . . . |
| Wheat shorts | 88.2 | 12.2 | 50.0 | 3.8 | 28.2 | 13.5 | 5.9 |
| Rye | 88.4 | 9.9 | 67.6 | 1 1 | 17.6 | 8.2 | 5.4 |
| Rye shorts | 90.7 | 11.9 | 45.1 | 1.6 | 18.4 | 12.6 | 8.1 |
| Oats | 89.0 | 9.2 | 47.3 | 4.2 | 20.6 | 8.2 | 6.2 |
| Oatmeal | 92.1 | 11.5 | 52.1 | 5.9 | 23 5 | . . . . | . . . . |
| Oat feed or shorts | 92.3 | 12.0 | 46.9 | 2.8 | 17.2 | 9.1 | 5.3 |
| Buckwheat | 87.4 | 7.7 | 49.2 | 1.8 | 14.4 | 4.4 | 2.1 |
| Buckwheat shorts | 88.9 | 21.1 | 33.5 | 5.5 | . . . . | . . . . | . . . . |
| Kaffir corn | 84.8 | 7 8 | 57.1 | 2.7 | . . . . | . . . . | . . . . |
| Millet | 86.0 | 8 9 | 45.0 | 3.2 | 20.4 | 8.5 | 3.6 |
| Cottonseed-meal | 91.8 | 37.2 | 16.9 | 12 2 | 67.9 | 28.8 | 8.7 |
| Sunflower seed | 92.5 | 12.1 | 20.8 | 29.0 | 22.8 | 12.2 | 5.6 |
| Soja (soy) bean | 89.2 | 29 6 | 22.3 | 14.4 | 53.0 | 18.7 | 19.0 |
| Cow-peas | 85.2 | 18.3 | 54.2 | 1.1 | 33.3 | . . . . | . . . . |
| *Roughage.* | | | | | | | |
| Fodder corn, green | 20.7 | 1.0 | 11.6 | 0.4 | 4.1 | 1.5 | 3.3 |
| Fodder corn, field | 57.8 | 2.5 | 34.6 | 1.2 | 17.6 | 5.4 | 8.9 |
| Corn stover, field | 59.5 | 1.7 | 32.4 | 0.7 | 10.4 | 2.9 | 14 0 |
| Kentucky blue-grass | 34.9 | 3.0 | 19.8 | 0.8 | . . . . | . . . . | . . . . |
| Timothy, dif. stages | 38.4 | 1.2 | 19.1 | 0.6 | 4.8 | 2.6 | 7.6 |
| Redtop, in bloom | 34.7 | 2.1 | 21 2 | 0.6 | . . . . | . . . . | . . . . |
| Hungarian grass | 28.9 | 2.0 | 16.0 | 0 4 | 3.9 | 1.6 | 5.5 |
| *Hay.* | | | | | | | |
| Timothy | 86.8 | 2.8 | 43.4 | 1.4 | 12.6 | 5.3 | 9.0 |
| Redtop | 91.1 | 4.8 | 46.9 | 1.0 | 11.5 | 3.6 | 10.2 |
| Kentucky blue-grass | 78.8 | 4.8 | 37 3 | 2.0 | 11.9 | 4.0 | 15.7 |
| Hungarian-grass | 92.3 | 4.5 | 51.7 | 1.3 | 12.0 | 3.5 | 13 0 |
| Mixed grasses | 87.1 | 5 9 | 40.9 | 1.2 | 14.1 | 2.7 | 15.5 |
| Soja-bean hay | 88.7 | 10.8 | 38.7 | 1.5 | 23.2 | 6.7 | 10 8 |
| *Straw.* | | | | | | | |
| Wheat | 90.4 | 0.4 | 36.3 | 0.4 | 5.9 | 1.2 | 5.1 |
| Rye | 92.9 | 0.6 | 40 6 | 0.4 | 4.6 | 2.8 | 7.9 |
| Oat | 90.8 | 1.2 | 38 6 | 0.8 | 6.2 | 2.0 | 12.4 |
| *Fresh Legumes.* | | | | | | | |
| Red clover, dif. stages | 29.2 | 2 9 | 14.8 | 0.7 | 5.3 | 1.3 | 4.6 |
| Crimson clover | 19 1 | 2.4 | 9.1 | 0 5 | 4 3 | 1 3 | 4.9 |
| Alfalfa | 28.2 | 3 9 | 12.7 | 0.5 | 7.2 | 1.3 | 5.6 |
| Cow-peas | 16.4 | 1.8 | 8.7 | 0.2 | 2.7 | 1.0 | 3.1 |
| Soja-bean | 24.9 | 3.2 | 11.0 | 0.5 | 2.9 | 1 5 | 5 3 |
| *Legume hay and straw* | | | | | | | |
| Red clover, medium | 84.7 | 6 8 | 35.8 | 1.7 | 20.7 | 3.8 | 22.0 |
| White clover | 90.3 | 11 5 | 42.2 | 1.5 | 27.5 | 5.2 | 18.1 |
| Crimson clover | 90.4 | 10 5 | 34.9 | 1.2 | 20.5 | 4.0 | 13.1 |
| Alfalfa | 91.6 | 11.0 | 39.6 | 1 2 | 21.9 | 5.1 | 16.8 |
| Cow-peas | 89.3 | 10.8 | 38.6 | 1 1 | 19.5 | 5.2 | 14.7 |
| Soja-bean | 89.9 | 2 3 | 40.0 | 1.0 | 17.5 | 4.0 | 13.2 |

## TABLE IV.*

FEEDING STANDARDS FOR FARM ANIMALS.

| THE ANIMAL. | PER DAY PER 1,000 POUNDS LIVE WEIGHT. | | | | |
|---|---|---|---|---|---|
| | *Dry Matter.* | DIGESTIBLE NUTRIENTS. | | | |
| | | *Protein.* | *Carbohydrates.* | *Ether Extract.* | *Nutritive ratio : 1 to* |
| 1. *Fattening Cattle.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | |
| First period | 30 | 2.5 | 15.0 | 0.5 | 6.5 |
| Second period | 30 | 3 0 | 14.5 | 0.7 | 5.4 |
| Third period | 26 | 2.7 | 15.0 | 0.7 | 6.2 |
| 2. *Growing Cattle.* Dairy Breeds. Age in months. Av. live wt. per head, lbs. | | | | | |
| 2–3 . . . . 150 | 23 | 4.0 | 13.0 | 2.0 | 4.5 |
| 6–12 . . . . 500 | 27 | 2.0 | 12.5 | 0.5 | 6.8 |
| 18–24 . . . . 900 | 26 | 1.5 | 12.0 | 0.3 | 8.5 |
| 3. *Growing Cattle.* *B.*—Beef Breeds. | | | | | |
| 2–3 . . . . 160 | 23 | 4.2 | 13.0 | 2.0 | 4.2 |
| 6–12 . . . . 550 | 25 | 2.5 | 13.2 | 0.7 | 6.0 |
| 18–24 . . . . 950 | 24 | 1.8 | 12.0 | 0.4 | 7.2 |
| 4. *Milch Cows, when yielding daily :* | | | | | |
| 11.0 pounds of milk | 25 | 1.6 | 10.0 | 0.3 | 6 7 |
| 16.6 pounds of milk | 27 | 2.0 | 11.0 | 0.4 | 6.0 |
| 27.5 pounds of milk | 32 | 3.3 | 13.0 | 0.8 | 4.5 |
| 5. *Horses.* | | | | | |
| Light work | 20 | 1.5 | 9.5 | 0.4 | 7.0 |
| Medium work | 24 | 2.0 | 11.0 | 0.6 | 6.2 |
| Heavy work | 26 | 2.5 | 13.3 | 0.8 | 6.0 |
| 6. *Sheep.* | | | | | |
| Coarse wool | 20 | 1.2 | 10.5 | 0.2 | 9.1 |
| Fine wool | 23 | 1.5 | 12.0 | 0.3 | 8.5 |
| 7. *Fattening Sheep.* | | | | | |
| First period | 30 | 3.0 | 15.0 | 0.5 | 5.4 |
| Second period | 28 | 3.5 | 14.5 | 0.6 | 4.5 |
| 8. *Fattening Swine.* | | | | | |
| First period | 36 | 4.5 | 25.0 | 0.7 | 5.9 |
| Second period | 32 | 4.0 | 24.0 | 0.5 | 6.3 |
| Third period | 25 | 2.7 | 18.0 | 0.4 | 7.0 |
| 9. *Growing, Fattening Swine.* Age in months. Av. live wt. per head, lbs. | | | | | |
| 2–3 . . . . 50 | 44 | 7.6 | 28.0 | 1.0 | 4.0 |
| 5–6 . . . . 150 | 33 | 4.3 | 22.3 | 0.6 | 5.5 |
| 9–12 . . . . 300 | 26 | 3.0 | 18.3 | 0.3 | 6.4 |

* These tables are adapted from Henry's *Feeds and Feeding*.

2. *Calculating the Heat-producing Material in Corn.*—In the table the ether extract in corn (all analyses) is given as 4.3; multiplying by 2.4, b. 132 the product is 10.32 pounds. The carbohydrates are given as 66.71 pounds. Adding the heat value of the ether extract (10.32 pounds) to the carbohydrates given, the sum is 77.02 pounds, the total heat-producing material in 100 pounds of corn.

**I. Analysis of Feeding Stuffs.**

1. *The amount* of carbohydrates, of ether extract, and of protein in a given food has been ascertained by repeated analyses. These amounts vary in different samples of the same kind of food, but the average results of a large number of analyses are used as a basis for the tables.

2. *Per cent. of Digestibility.*—But the *amount* of nutrients *contained* in a food is not enough to know. One must know what per cent. of it is available—that is, what per cent. of it the animal in a given condition is able to digest and assimilate. Many experiments* have been and are being made to find out the per cent. of these nutrients actually digested. Some of the results are given in table III.

**II. Wolff-Lehmann Feeding Standards.**

1. *A Balanced Ration.*—Not only is it essential to know the amount of digestible protein,

* Henry's *Feeds and Feeding*, pp. 26, 27.

carbohydrates, and ether extract, but it is important to know the *proportion* of each of these two kinds (tissue-forming and heat-producing) of digestible nutrients in the feed required to produce the best results in different animals under various conditions of development or requirements of work. Such a food, or combination of foods, for each day is called "a balanced ration."

2. *How the Standards were Obtained.*—Many feeding trials have been made for the purpose of ascertaining the ratio which should exist between the two kinds—heat and energy producing and tissue-forming nutrients.

The feeding standards originally prepared by Dr. Emil v. Wolff and modified by Dr. C. L. Lehmann—hence, called the Wolff-Lehmann feeding standards—are the results of such trials, and while these standards (see Table IV.) are not to be considered absolute, they are based upon actual results obtained by repeated trials of various combinations of these nutrients. "The standards are arranged to meet the requirements of farm animals under normal conditions."

3. *These Standards are Used Only as a Basis.*—This table, while giving the actual amounts digested by the animals which were fed, is only approximately true for other animals under similar conditions, for the amount digested depends

not alone upon the food, but upon the breed, individuality, and condition of the animal fed.

These standards are excellent as a *basis* for feeding and for comparison. No stockman should omit the results of his own experience—if he has kept an accurate record of feeds and their results—as an element in deciding upon a suitable ration for different animals at different stages of development or different requirements of work.

4. *Nutritive Ratio.*—The ratio between the protein and the heat-producing elements (carbohydrates and ether extracts) for any kind of food, or combination of foods, is called the nutritive ratio. For example, in the daily food required—20 pounds dry matter—for a horse doing light work, the amount of digestible protein is 1.5 pounds; carbohydrates, 9.5 pounds; ether extract, .4 pounds. Multiplying the number of pounds of ether extract, .4, by 2.4, or its heat value, the result is .96 pounds; this, plus the carbohydrates, 9.5 pounds, is equal to 10.46 pounds. Dividing the 10.46 pounds of heat-producing elements by the number of pounds of protein, 1.5, the result is 7:; therefore, the nutritive ratio of this food is 1:7.

Board

EXERCISE 6.—(*a*) What is the *nutritive ratio* of a food containing .7 pounds of protein, 8 pounds of carbohydrates, and .1 pound ether extract? 1:11.77+

(*b*) If the nutritive ratio of a food is 1:7.7, and the

ether extract .3, and the carbohydrates 10., how much protein does it contain? 1.4 – lbs.

(*c*) If the nutritive ratio of a food is 1:5.2, the protein 2.8, and the ether extract .8, how much carbohydrate does it contain? 5.2 × 2.8 = 14.56   .8 × 2.4 = 1.92
1.92
12.64 lbs. carbohydrates

4. *Wide and Narrow Ratios.*—When the amount of carbohydrate and ether extract is large in proportion to the amount of protein, *the ratio is called wide.* For example, the nutritive ratio of corn stover is 1:20, and that of oat straw 1:33.7. Both of these would be called wide ratios. When the amount of heat-producing elements is small in proportion to the amount of protein, the ratio is said to be *narrow*, as in oil meal, where it is 1:1.7.

In Indian corn the ratio is 1:9.8, and is called *medium*. As is shown by the table, a medium ratio most often gives the best result, growing and heavily worked animals (as young cattle, 1:4.5, and heavily worked horses, 1:6) requiring a narrower ration—that is, containing a greater proportion of protein to carbohydrates—than the mature animal, ~~or animal,~~ or those doing light work (as, 18:24 months old dairy cattle, 1:8.5, and a horse doing light work, 1:7). This is due to the fact that protein is needed in the growing and working animal for the upbuilding of tissues.

It will be noticed that there is no wide nutritive ratio given in the table, as in that case the

protein of the food would not be sufficient to maintain the tissues of the body. Neither is there given an extremely narrow ratio, for that would necessitate the consumption of protein for the production of heat and energy. When a food containing a medium nutritive ratio is fed there are sufficient carbohydrates to supply the heat and energy, and protein enough to maintain the body, and either to build up additional tissues in growth or flesh, or to be used in the production of milk.

5. *Compounding Rations.*—It is not often that any one kind of food will supply the desired ratio of nutrients, so it is necessary to combine several kinds in such proportions as to give that ratio in the combined food. For example, if timothy hay (the nutritive ratio of which is 1:16.7) forms the rough food, a balanced ration can only be obtained by combining with it some highly concentrated food—as, cottonseed-meal, whose nutritive ratio is 1:1.2; while if hay from clover, cow-peas, or alfalfa, is used, corn and oats will be sufficient, if used in proper proportions, to form a balanced ration.

EXERCISE 7.—Finding, or estimating, a ration for 1,000 pounds of live weight according to the standard in the table.

Problem: To determine the ration for a horse weighing 1,000 pounds and doing light work. According to the table, the following standard is required: dry mat-

ter, 20 pounds; protein, 1.5; carbohydrates, 9.5 pounds; ether extract, 0.4 pounds, and the nutritive ratio, 1: 7.

All that is necessary is to find such a combination of foods as will make a nutritive ratio of 1:7 and furnish approximately 20 pounds of dry matter. For a trial ration, assume 15 pounds of red clover hay and 10 pounds of oats.

*First Trial.*—Required to find the number of pounds of dry matter, protein, carbohydrates, and ether extract, respectively, in 15 pounds of clover hay and 10 pounds of oats.

(*a*) In 100 pounds of clover hay there are, according to the table, 84.7 pounds of dry matter, 6.8 pounds of protein, 35 8 pounds of carbohydrates, and 1.7 pounds of ether extract.

Then in 15 pounds of clover hay there are:

$15 \times \frac{84.7}{100} = 12.7$ of dry matter;
$15 \times \frac{6.8}{100} = 1.02$ pounds of protein;
$15 \times \frac{35.8}{100} = 5.37$ pounds of carbohydrates; and
$15 \times \frac{1.7}{100} = .25$ pounds of ether extract.

(*b*) In 100 pounds of oats there are, according to the table, 89 pounds of dry matter, 9.2 pounds of protein, 47.3 pounds of carbohydrates, and 4.2 pounds of ether extract.

Then in 10 pounds of oats there are:

$10 \times \frac{89}{100} = 8.9$ pounds of dry matter;
$10 \times \frac{9.2}{100} = .92$ pounds of protein;
$10 \times \frac{47.3}{100} = 4.73$ pounds of carbohydrates; and
$10 \times \frac{4.2}{100} = 4.2$ pounds of ether extract.

Adding the amounts of these different substances contained in:

| | Dry Matter. | Protein. | Carbohydrates. | Ether Extract. |
|---|---|---|---|---|
| Clover, 15 lbs. | 12.7 | 1.02 | 5.37 | .25 |
| Oats, 10 lbs. | 8.9 | .92 | 4 73 | .42 |
| The sum is. | 21.6 | 1.94 | 10.10 | .67 |

The nutritive ratio, then, is 1 to the quotient obtained by dividing the sum of $10.10 + (2.4 \times .67) = 11.708$ by $1.94 = 6$. Therefore, the nutritive ratio is 1:6.

Comparing this with the standard, we find that the ratio is that given for a horse doing *heavy* work, while the nutritive ratio given for a horse doing *light* work is given as 1:7. A horse at light work requires less protein than one doing heavy work; hence, this ratio is too narrow. Then, as another trial, let five pounds of oat straw be substituted for five pounds of the clover hay.

*Second Trial.*—Required to find the number of pounds of dry matter, protein, carbohydrates, and ether extract, respectively, in 10 pounds of clover hay and 5 pounds of oat straw.

(*a*) In 100 pounds of clover hay there are, according to the table, 84.7 pounds of dry matter, 6.8 pounds of protein, 35.8 pounds of carbohydrates, and 1.7 pounds of ether extract.

Then in 10 pounds of clover hay there are:

$10 \times \frac{84.7}{100} = 8.47$ pounds of dry matter;

$10 \times \frac{6.8}{100} = .68$ pounds of protein;

$10 \times \frac{35.8}{100} = 3.58$ pounds of carbohydrates; and

$10 \times \frac{1.7}{100} = .17$ pounds of ether extract.

(*b*) In 100 pounds of oat straw there are, according to the table, 90.8 pounds of dry matter, 1.2 pounds of protein, 38.6 pounds of carbohydrates, 0.8 pounds of ether extract.

Then in 5 pounds of oat straw there are:

$5 \times \frac{90.8}{100} = 4.54$ pounds of dry matter;
$5 \times \frac{1.2}{100} = .06$ pounds of protein;
$5 \times \frac{38.6}{100} = 1.93$ pounds of carbohydrates; and
$5 \times \frac{0.8}{100} = .04$ pounds of ether extract.

Adding the amounts of these different substances contained in:

| | *Dry Matter.* | *Protein.* | *Carbohydrates.* | *Ether Extract.* |
|---|---|---|---|---|
| Clover, 10 lbs. | 8.47 | .68 | 3.58 | .17 |
| Oats, 10 lbs. | 8.9 | .92 | 4.73 | .42 |
| Oat straw, 5 lbs. | 4.54 | .06 | 1 93 | .04 |
| The sum is | 21.91 | 1.66 | 10.24 | .63 |

The nutritive ratio is 1:7.

Comparing this second trial ration with that of the standard, we find that the nutritive ratio is that given for a horse doing *light* work.

EXERCISE 8.—(1) For fattening cattle, compound a ration having a nutritive ratio of 1:5.4 containing two different kinds of roughage and one concentrate. Bring result

(2) For a milch cow, compound a ration consisting of red clover, hay, corn silage, oat straw, and wheat bran, and having a nutritive ratio of 1:7, and approximating 25 pounds of dry matter.

(3) For cattle, compound a maintenance ration having a nutritive ratio of 1:10, and approximating 18 pounds of dry matter.

1 lb. cottonseed meal is equal to By test of So. Car.

(4) (*a*) Let each student compute the nutritive ratio of a ration with which he is actually feeding, or knows is being fed, to a cow or a horse.

(*b*) Does the condition of the animal justify the continuance of this ration? Why?

(*c*) How does this nutritive ratio compare with that of the standard given for an animal under similar conditions.

(*d*) If this ratio is too wide or too narrow, is it on account of the kinds of food, or on account of the proportion of the different kinds of food? Modify this ration so that the nutritive ratio will agree with that of the standard.

## *E*.—FEEDING STUFFS.

Wherever it is possible, the food fed to the stock should be *grown* on the farm and not bought.

In deciding upon a ration for a given animal, the stockman should know two things: (1) what the animal needs; (2) what the food contains. Then he can determine what foods will supply the demands of the animal in question.

**I. Palatability**
of foods is of no little importance, for if from any reason the animal does not relish the food, enough will not be eaten to produce any gain. Animals tire of the same food used continuously, just as man does; hence an occasional change in the food is a good plan, but this should be done in such a manner as not to materially change the nutritive ratio.

**II. Kinds.**

1. *Concentrate.*—A food which contains a minimum amount of crude fiber and water in proportion to the nutrients is called a *concentrate.*

2. *Roughage.*—A food which contains a large amount of crude fiber or of water in proportion to its nutritive elements is called *roughage,* coarse food, or forage.

The element of bulk must be taken into consideration in determining a ration, especially for a ruminant. If a food is too concentrated, a sufficient amount of digestible nutrients do not distend the digestive organs, and the juices of the stomach and intestines cannot work upon the food effectively. If the food is too bulky, enough cannot be eaten to supply the proper nutrients, or too much energy is consumed in the eating of it. About two-thirds of the dry matter in the ration for ruminants should be coarse food and one-third concentrated food; for work-horses, the food should be about half and half of each.

As will be seen from the tables, the concentrates contain a much greater per cent. of protein than the coarse foods do. Those having the greatest proportion of protein (see table) are cottonseed-meal, soy-bean, buckwheat shorts, and cow-peas.

There are two kinds of roughage: (1) dry

forage—as, hay, fodders, etc.—and (2) green forage—as, pasture, soiling crops, and silage.

(2) Green Forage.—(*a*) Pasture.—Animals on pasture seem to be in their natural environment and need very little concentrated food compared with those of the same grade fed upon dry forage. Green food contains a much less per cent. of digestible nutrients on account of the large per cent. of water, and hence it is necessary to eat a greater quantity, and an animal in pasture expends much energy in walking over the pasture to secure the food and in masticating the extra quantity. For this reason the method of feeding called "soiling" is advocated by many experiment stations.

(*b*) Soiling is the feeding of forage crops *green* to stock confined in covered barn-yards. Experiments conducted at various stations prove that a greater number of animals can be fed from the same number of acres than can be fed by pasturing.

At the Wisconsin experiment station it was found that one acre of a soiling crop equaled two and a half acres of good blue-grass pasture for feeding dairy cows. A dairy cow requires from 60 to 100 pounds of green forage daily.

It is objected that the practice of soiling involves extra work. But green forage need only be gathered twice a week if thinly spread upon

the floor of the barn, and most crops can be cut with the mower; so, after all, it will not require much time. Especially should this plan of feeding supplement the pasture by supplying some green forage—as, rye early in the spring, and soy-beans when the pasture becomes short and dry in midsummer (see "Rotation of Crops," Course 7).

It is at this latter period that the heat is so oppressive and the flies so troublesome, and if the stock can be housed in a darkened but well-ventilated place in the daytime, and turned into the pasture at night, much greater comfort to the animal and a gain in milk or flesh will result.

There is another economical problem which the covered barn-yard (see Fig. 29) solves. It is that of saving the waste, that it may be returned to the soil as a fertilizer (see "Fertilizers"). Not only is the soil benefited by the fertilizing material returned to it, but soiling crops are very useful in helping to form the courses in rotation (see Courses 5 and 7), which are most beneficial to the soil and most profitable to the farmer.

(*c*) Silage.—There is a time of year in the greater portion of this country when neither pasturing nor soiling is possible. Science has again come to the aid of the stockman, and found a way to provide green food in winter.

It is by preserving green forage in a silo* (see Fig. 35), on the same principle that green fruits are preserved for winter use by canning—that is, *by excluding the air.*

The advantages of silage are stated as follows by Professor H. J. Waters, Director of the Missouri Agricultural Experiment Station:

"(*a*) Green and succulent food is thereby provided for the winter months.

"(*b*) The green plant is more palatable, the coarser parts of the stalk being much more completely consumed when made into silage.

"(*c*) A large quantity of material may be stored in a comparatively small space.

"(*d*) The harvesting is done during the pleasant weather in the early fall, and the drudgery of handling dry stover in winter is obviated.†

"(*e*) It is cheaper, on the whole, than to be at the expense of husking and grinding the ears and cutting and shredding the stover. It does not appear to affect the digestibility of the material either favorably or unfavorably."

If the silage is not all used during the winter months, it can be fed when needed in the summer to take the place of soiling crops.

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* For full discussion of silo and silage, send for a book on silage, by F. W. Woll, Silver Manufacturing Co., Salem, Ohio.

† Since the forage used for silage is put into the silo as soon as cut, there is no occasion for loss by unfavorable weather, as is so often the case with hay.

FIG. 35.—ROUND SILO. (MISSOURI AGRICULTURAL COLLEGE FARM.)

Diameter, 18 feet; hight, 30 feet; capacity, 150 tons. Cost, $175.00.

Corn and clover are most often used in making silage. Silage is recommended not only as an excellent food for the dairy cow and for sheep, but it forms a good substitute for oats as a food for fattening cattle. It should constitute from two-thirds to three-fourths of the roughage for cows; alfalfa, clover, or cow-peas constituting the remainder of the coarse food.

## F.—REFERENCES.

"Feeds and Feeding." Henry. Published by the author. Madison, Wisconsin.

"The Fertility of the Land." Roberts. 10.

"Feeding the Dairy Cow." Bulletin 58, Missouri Agricultural Experiment Station.

"Stock Feeding." Bulletin 67, South Carolina Agricultural Experiment Station.

"Feeding Stuffs." Bulletin 107, Virginia Agricultural Experiment Station.

"Feeding Stuffs." Bulletin 12, West Virginia Agricultural Experiment Station.

"Concentrated Feeding Stuffs." Bulletin 165, New Jersey Agricultural Experiment Station.

"Stock Feeding." Bulletin 67.

"Feeding of Animals." Jordan. 10.

325 x as much water required than dry matter produced.

5th hour - recite.

# OUTLINE OF CHAPTER VII.

4th hour

## ROTATION OF CROPS.

### *A.*—INFLUENCE OF ROTATION UPON PLANT-FOOD.

**I. Preserves Food Supply.**

1. *Prevents Exhaustion.*
2. *Prevents Loss by Exposure*

**II. Increases Food Supply.**

1. *Renders Plant-food Available.*
2. *Brings Up Plant-food from the Subsoil.*
3. *Facilitates Fertilizing.*

### *B.*—ROTATION AS AFFECTING THE ENEMIES OF PLANTS.

**I. Eradicates Weeds.**

**II. Exterminates Insect Pests.**

### *C.*—PROFIT IN ROTATION.

### *D.*—SELECTING THE COURSE IN ROTATION.

**I. What Can Be Successfully Grown?**

**II. What Can Be Successfully Used or Sold?**

### *E.*—BETTER DISTRIBUTION OF LABOR.

### *F.*—SUGGESTED COURSES IN ROTATION.

### *G.*—TABLE OF SOILING CROPS.

### *H.*—CATCH, OR COVER, CROPS.

### *I.*—KEEPING ACCURATE ACCOUNTS.

EXERCISE 9.

### *J.*—REFERENCES.

# CHAPTER VII.

## ROTATION OF CROPS.

Many of the problems that confront the farmer of the present day might have been avoided had Rotation of Crops been more often practiced by our fathers. The productiveness of the soil cannot continue for any considerable length of time unless rotation, or change of crops, is practiced, or fertilizers heavily applied.

### *A.*—INFLUENCE OF ROTATION UPON PLANT-FOOD.

**I. Preserves Food Supply.**

1. *Prevents Exhaustion.*—Different plants require different proportions of the various foods. If the same crop—as, wheat or cotton—is grown continuously for a number of years, the soil in that field may become so deficient in certain elements essential to that particular crop as to very materially lessen the yield; while if some other crop, as clover, be sown, the yield may be very heavy, and hence the crop may be more profitable, even at a lower price. Crops should be so selected that different plant-foods—or, at least, different proportions of the plant-foods—will be demanded from the soil each year.

2. *Prevents Loss by Exposure.*—The materials from the soil are not only taken up by the plants, but continuous free and open cultivation exposes the humus of the soil to the sun and to the oxygen of the air, and *more of its nitrogen* is made soluble than can be taken up by the plants; hence, it is *washed out* and *carried away* by the rains (Fig. 8). (See under "Cover Crops," p. 159.)

**II. Increases Food Supply.**

1. *Renders Plant-food Available.*—Repetition of certain kinds of crops—as, timothy or blue-grass—tends to use up the food faster than it is rendered available, while change of crops and consequent cultivation hastens the breaking up of the chemical compounds in the soil, and thus renders plant-food available.

2. *Brings Up Plant-food from the Subsoil.*—The food supply may be further increased by rotating clover, or any legume (all of which have deep-feeding roots), with a crop of corn, or wheat (Fig. 36), which has surface-feeding roots. In this way the deep-feeding roots bring up food elements from the subsoil, and when these roots decay these food materials are accessible to the surface-feeding plants.

3. *Facilitates Fertilizing.*—Rotation not only prevents the exhaustion of the fertility of the soil, but may be useful in making artificial fer-

Missouri Experiment Station.

FIG. 36.—WHEAT GROWN AFTER COW-PEAS.

A crop of cow-peas was grown each year in this acre plot. Yield of wheat on this acre for four years (1900-1903), 144 bushels.

tilizing successful. For example, if stable compost be applied immediately preceding crops of small grain—as, wheat or oats—it may injure the crop by tending to produce straw rather than grain; while if it be applied before corn is planted, it will result in an increased yield of corn, and a better condition of the soil for subsequent crops (see Fig. 27, "Showing Effect of Nitrate," p. 80).

## *B.*—ROTATION AS AFFECTING THE ENEMIES OF PLANTS.

### I. Eradicates Weeds.

Short rotations with wheat and clover tend to eradicate weeds. If a field becomes overrun with certain weeds—as, the broad-leafed plantains—they may be eradicated in a few years by short rotations of winter wheat, or rye, with clover. The clover should be sown upon the wheat early in the spring. The wheat will not be damaged by the weeds, as they do not seed before it is cut, while the same will be true of the clover the following year. The clover stubble should be plowed at once to avoid the seeding of the weeds.

It would then be well to thoroughly prepare the soil and put it in turnips, or some hoed crop, until time to sow the fall wheat, when the ground may be prepared by harrowing.

Certain kinds of weeds are found in certain kinds of crops; then, if the field is weedy, this particular crop should not be grown until these weeds are killed out.

### II. Exterminates Insect Pests.

Again, certain crops are more apt to be infested with particular insect pests (see "Enemies of Plants"), or fungous (parasitic) plants. If it is known that such enemies have even a start upon a certain field, that crop should not be grown upon it the following year, nor until the pest, whatever it may be, is eradicated. Co-operation of neighbors can greatly facilitate this work.

## *C.*—PROFIT IN ROTATION.

If there is one crop which can be grown upon a field that is more profitable than another crop, it is the first one to be considered in the system of rotation. This crop, however, should not be repeatedly grown, but such a rotation should be chosen as will best fit the ground for the largest yield of the best-paying crop.

## *D.*—SELECTING THE COURSE IN ROTATION.

### I. What Can Be Successfully Grown?

This will depend upon the kind of soil, the climate, and the seasons. The poorer the soil the shorter the course, and the richer the soil the longer the course of rotation may be.

**II. What Can Be Successfully Used or Sold?**

This is another question to be considered in selecting the course in rotation. The answer to this question will depend upon the farmer's facilities for keeping and feeding certain kinds of stock, or upon the location as regards markets for farm crops.

### *E.*—BETTER DISTRIBUTION OF LABOR.

Rotation of farm crops not only makes better farms, but it makes better men. In the great grain districts the work requires many men for a short time, and is much less to be desired than to have several successive crops, which distribute the labor throughout the year and enable it to be done by a less number of men, thus making homes and true civilization possible.* A few courses in rotation are suggested below.

### *F.*—SUGGESTED COURSES IN ROTATION.

1. Clover, corn, oats, and wheat.
2. Clover, corn, potatoes, and wheat.
3. Clover, corn, and wheat.
4. Clover and timothy, mixed, two years, corn, wheat, and cow-peas.
5. Cow-peas or clover, cotton, and wheat.
6. Peanuts, cotton, and wheat.
7. For soiling crops: Rye, soy-beans, winter wheat, and clover.

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* Roberts' *The Fertility of the Land*, p. 369.

## *G.*—TABLE V.

SOILING CROPS.*

| CROPS. | *Seed per Acre.* | *Time of Seeding.* | *Area.* | *Time of Cutting.* |
|---|---|---|---|---|
| Rye . . . . . . . . | 2 bushels | Sept. 10–15 | ½ acre | May 20 May 30 |
| Wheat . . . . . . . | 2 bushels | Sept. 10–15 | ½ acre | June 1–June 15 |
| Red clover . . . . | 20 lbs. | July 15–Aug. 1 | ½ acre | June 15–June 25 |
| Grass and clover . | ½ bú. red top<br>¼ bu. timothy<br>10 lbs. r. clover | September | ⅔ acre | June 15–June 30 |
| Vetch and oats . . | 3 bu. oats<br>50 lbs. vetch | April 20 | ½ acre | June 25–July 10 |
| Vetch and oats . . | 50 lbs. vetch | April 30 | ½ acre | July 10–July 20 |
| Peas and oats . . | 1½ bu. Canada<br>1½ bu. oats . . | April 20 | ½ acre | June 25–July 10 |
| Peas and oats . . | 1½ bu. Canada<br>1½ bu. oats | April 30 | ½ acre | July 10 |
| Barnyard millet . | 1 peck | May 10 | ⅓ acre | July 25–Aug. 10 |
| Barnyard millet . | 1 peck | May 25 | ⅓ acre | Aug. 10–Aug. 20 |
| Soja bean . . . . . | 18 quarts | May 20 | ⅓ acre | Aug. 25–Sept. 15 |
| Corn . . . . . . . | . . . . . . . . . . | May 20 | ⅓ acre | Aug. 25–Sept. 10 |
| Corn . . . . . . . . | . . . . . . . . . . | May 30 | ⅓ acre | Sept. 10–Sept. 20 |
| Hungarian . . . . | 1 bushel | July 15 | ½ acre | Sept. 20–Sept. 30 |
| Barley and peas . . | 1½ bu. peas<br>1½ bu. barley | Aug. 5 | 1 acre | Oct. 1–Oct. 20 |

The above table of plants *used for soiling* may be helpful in selecting short crops in a rotation.

## *H.*—CATCH, OR COVER, CROPS.

Catch, or cover crops—as, crimson clover, cow-peas, rye, Kafir-corn, teosinte, and vetch—may often be grown in the time intervening between the principal crops of the year with very little labor and often with much profit. A field which is used in short rotations loses no more of its fertility than one which lies idle aud loses its substance by exposure to the weather, or gives it up to weeds.

* Henry's *Feeds and Feeding*, p. 233.

## *I.*—KEEPING ACCURATE ACCOUNTS.

This is as essential on the farm as in the bank or store; for the farmer should know just what his profit is, and what crops pay best. This can be known only by keeping account of all work done and money expended in putting in and in harvesting the crop, and in the feeding or marketing of it.

EXERCISE 9.—(*a*) Each student should carefully prepare an original plan for a course in rotation upon a poor soil, and another upon a fertile soil, in his own vicinity.

(*b*) Give directions for the preparation of the soil as regards fertilization and tillage.

(*c*) Give directions and reasons for the disposition of each of these various crops. Is it to be fed, or sold? If fed, in what condition—green or dry? To what animals?

(*a*) Make an estimate of the probable cost of seed and work, and of the value of the crop; if sold; if fed; and calculate the gain.

(*e*) Read and discuss in class each plan, with reasons. Be able to defend every point taken.

## *J.*—REFERENCES.

"Practices in Crop Rotation." Year-book, 1902.
"The Fertility of the Land." Roberts. 10.
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# OUTLINE OF CHAPTER VIII.

## MILK AND ITS CARE.

C. H. ECKLES,
*Dairy Husbandry, Missouri Agricultural Experiment Station.*

### *A.*—MILK.

**I. Secretion.**

**II. Care of Milk.**

1. *Sources of Abnormal Odors.*
   (1) CERTAIN FOODS.
   (2) THE AIR.
   (3) BACTERIA.
2. *Keeping Bacteria Out of Milk.*
3. *Preventing Growth of Bacteria.*
   (1) LOW TEMPERATURE.
   (2) PASTEURIZATION.

**III. Composition.**

1. *Butter Fat.*
2. *Casein and Albumen.*
   (1) CASEIN.
   (2) ALBUMEN.
3. *Milk Sugar.*
4. *Ash.*

**IV. Color.**

**V. Variation in Quantity and Quality.**

1. *Breed of Animals.*
2. *Individuality.*
3. *Period of Lactation.*
4. *Feed.*
5. *External Conditions.*
6. *First and Last Milk Drawn.*
7. *Intervals between Milkings.*

**VI. The Babcock Test.**

1. *The Need of a Test for Butter Fat.*
2. *The Babcock Method.*
   (1) TEST-BOTTLES.
   (2) PIPETTE.
   (3) ACID MEASURE.
   (4) CENTRIFUGAL MACHINE.
   (5) SAMPLING MILK.
   (6) MAKING THE TEST.
   (7) READING THE TEST.
   (8) TESTING SKIM-MILK AND BUTTERMILK.
   (9) TESTING CREAM.
   Weigh Out Cream for Testing.

### *B.*—CREAM.

**I. Separation of Cream.**

1. *By Gravity.*
   (1) SHALLOW PANS.
   (2) DEEP SETTING.
   (3) DILUTION.
2. *By Centrifugal Force.*

**II. Ripening Cream.**

### *C.*—BUTTER.

**I. Coloring.**

**II. Kinds of Churns.**

**III. Churning.**

1. *Temperature.*
2. *Other Factors Affecting Time of Churning.*
3. *When to Stop Churning.*

**IV. Washing Butter.**

**V. Salting.**

**VI. Working.**

**VII. Composition of Butter.**

**VIII. Overrun.**

**IX. Packing and Marketing.**

### *D.*—REFERENCES.

# CHAPTER VIII.

## MILK AND ITS CARE.

C. H. ECKLES,
*Dairy Husbandry, Missouri Agricultural Experiment Station.*

### *A.*—MILK.

### I. Secretion of Milk.

Milk is a fluid secreted by the mammary glands of all animals that suckle their young. It contains all the elements of nutrition necessary for the nourishment of the young animal in a palatable and easily digested form.

The material forming milk is all taken from the blood, but changed in nature by the secreting cells so that no constituent of milk, except water, is found in the blood in the same form.

In the wild state the cow only gave milk enough to nourish the calf until it could subsist on other food. Under domestication of the cow the secretion of the milk has been greatly increased by careful selection and liberal feeding.

### II. Care of Milk.

The conditions under which milk is handled are of the greatest importance, whether it be used as food or manufactured into butter or cheese.

1. *Sources of Abnormal Odors.*—Milk begins to decompose and possesses abnormal odors

and tastes after standing for some time, and occasionally these are present when it is milked. There are three common sources of these objectionable tastes and odors in milk.

(1) CERTAIN FOODS.—When food eaten by cows contains any strong volatile substance, this will be carried through the circulation of the cow and into the milk. For example, when a cow eats onions, turnips, or even some strong weeds, the characteristic odor and taste may be recognized in the milk. These odors may be mostly driven off by heating the milk. Ordinarily very little trouble is experienced from this source, as the common feeds have no noticeable effect on the flavor of the milk.

(2) THE AIR.—Any odors, even if not very pronounced, may be readily absorbed from the air by milk or butter. Milk exposed to the air of an ill-kept barn, or a musty cellar, often absorbs odors that make it very objectionable for food.

(3) BACTERIA.—The most common cause of objectionable tastes and odors of milk is the action of various bacteria. Bacteria of many kinds are found in milk, and various kinds of fermentation result from their action. In addition to common souring, milk may be decomposed, giving off bad odors, may become ropy, or bitter, or even have an abnormal color due to the action of bacteria.

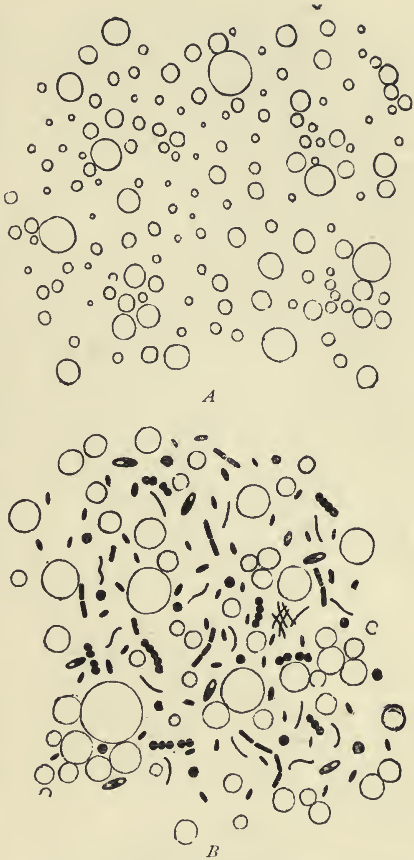


FIG. 37.—PURE AND IMPURE MILK HIGHLY MAGNIFIED.

*A*, pure milk; *B*, after standing in a warm room for a few hours in a dirty dish, showing, besides the fat globules, many forms of bacteria.

Most of the bacteria found in milk are perfectly harmless, although at times those causing diseases, such as typhoid fever, diphtheria, and tuberculosis, may get into the milk. It is impossible to keep all bacteria out of milk, but a great deal can be done toward keeping them out, and keeping those that do get in from growing (Fig. 37).

2. *Keeping Bacteria Out of Milk.*—This process may be summed up in one word—*cleanliness.*

The bacteria (Fig. 37) get into milk with dust particles from many sources, but the most

common and the worst contamination usually takes place in the barn. Very often the stable is not kept clean, the body of the cow becomes soiled, and, during milking, dust particles from the hair become loosened and drop into the milk-pail. The milker may wear dirty clothes, and the air of the barn may be full of dust, or the milk-vessels may not be perfectly clean.

The number of bacteria in the milk can be greatly reduced by observing the utmost cleanliness in every particular, especially about the barn, during milking, and by cleansing the utensils thoroughly. All milk-vessels should first be rinsed out with cold water, as hot water coagulates the albumen and makes it stick to the vessels. After this rinsing, they should be thoroughly *scalded and sunned* to kill any bacteria present.

3. *Preventing Growth of Bacteria.*—Next in importance to keeping bacteria out of milk is preventing those that do get in from growing rapidly.

(1) LOW TEMPERATURE is the chief factor to be relied upon. If it is desired to keep milk sweet for some time, it should be cooled at once after milking to 50° F., or lower if possible. If this is done, and this temperature maintained, milk will remain sweet several days, while if it is allowed to remain warm it will sour within twenty-four hours.

(2) PASTEURIZATION.—Another method of preventing the growth of bacteria in milk is that of Pasteurization (Fig. 38). This consists in heating milk to about 160° F. for twenty minutes, then rapidly cooling to 50° F. This kills about 99 per cent. of the bacteria, and the keeping quality of the milk is very much improved.

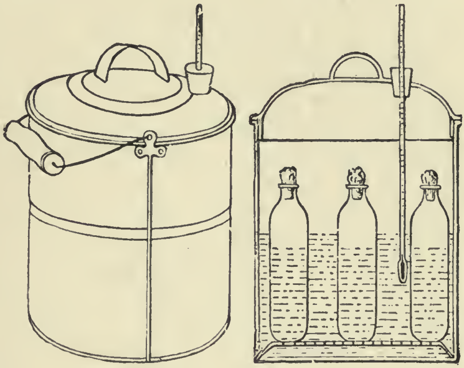


FIG. 38.—PASTEURIZING APPARATUS.

**III. Composition of Milk.**

The milk of all animals contains practically the same constituents, but varies greatly in the proportion of each. The average composition of cow's milk in America is as follows: Water, 87.5 per cent.; fat, 3.6 per cent.; casein, 2.9 per cent.; albumen, .5 per cent.; milk sugar, 4.75 per cent.; ash, or mineral, .75 per cent.

1. *Butter Fat.*—The butter fat is commercially the most valuable part of milk. It varies in amount more than any other constituent of milk except water. Wide variations from the average composition are constantly found. Fat seldom is less than 2.5 per cent., or more than

7 per cent. Butter fat is found in milk in the form of minute drops of oil, called globules. These globules vary in size from $\frac{1}{3000}$ to $\frac{1}{20000}$ of an inch in diameter (see *A*, Fig. 37). The number present in even a small amount of milk is beyond comprehension. This fat is made up of a mixture of ten or more distinct oils, the more important of which are *stearin*, *palmatin*, *olein*, and *butyrin*. The first two mentioned melt at a temperature above 140° F., while olein is liquid at 32° F. The hardness of a certain lot of butter depends upon the proportion of these oils present. Green food, such as grass, increases the proportion of olein, and accounts for the soft condition usually observed in butter made during the summer months.

Butyrin is the characteristic fat of butter, and is found only in butter fat. The chemical difference between butter and oleomargarine is largely the absence of butyrin in the latter.

The size of the fat globules (Fig. 37) in milk varies with the breed of the cow, the feed, and with the individual animal. It is of some importance on account of the relation it bears to the separation of cream and to churning. Large fat globules separate from the milk and form cream more quickly than do small ones, and with somewhat less loss of butter fat in the skim-milk. Cream composed of large fat globules churns more rapidly.

2. *Casein and Albumen.*—These constituents vary less in quantity than does butter fat. They are very similar in composition, and serve the same purposes as food, but differ widely in appearance. They differ from other parts of milk by containing sulphur, nitrogen, and phosphorus.

(1) CASEIN.—This constituent of milk may be seen as the curd which forms when milk sours. It is present in milk in a very finely divided condition in combination with lime. When milk sours, the acid unites with the lime, and the casein then becomes insoluble, and appears as the common curd of sour milk.

When milk is used for butter-making, the most of the casein remains in the skim-milk, some goes into the buttermilk, and a small amount into the butter, making upon the average 1 per cent. of the latter.

Casein is an important part of cheese, composing approximately one-third of common cheese.

(2) ALBUMEN.—This substance, as found in milk, is practically the same as the white of an egg. It differs from casein in being entirely in solution, making about .5 per cent. When milk is heated to 160°F., or above, the albumen is coagulated, and is seen as a tough scum on the surface.

When milk is used for butter-making, the

most of the albumen remains with the skim-milk and buttermilk. In cheese-making albumen remains in the whey, and is not incorporated into the cheese. The very disagreeable odors characteristic of decomposing milk are largely produced from albumen.

3. *Milk Sugar.*—This sugar, known by the chemist as lactose, has the same composition as common cane sugar ($C_{12}H_{22}O_{11}H_2O$), and is found only in milk. It appears, when separated, as a fine white powder, with a mild, sweet taste. Milk sugar is a common commercial article, being usually secured from whey as a by-product of cheese-making. When milk is used for butter-making almost all the sugar remains with the skim-milk and buttermilk, while in cheese-making it remains in the whey. Its chief importance in butter or cheese making is its relation to the souring of milk or milk products, which is due to the decomposition of the sugar through the action of minute forms of plant life called bacteria. By this act of decomposition, lactic acid is produced from the sugar, and this gives the common sour taste and causes the precipitation of the casein, as seen in soured milk.

4. *Ash.*—This is the portion that would remain if milk were burned. It consists of a mixture of several elements, the most important being lime, iron, potash, magnesium, sulphur, and phosphorus. These mineral matters are all

in combination with the casein and albumen, and make up about .7 per cent. of average milk.

**IV. Color.**

The normal white color of milk is mostly due to the casein. The yellow shade observed in varying degrees is due to a specific coloring matter called lactochrome, which is combined with the butter fat, and gives butter the natural yellow color. The amount of this coloring matter varies greatly, being affected the most by the feed of the cow, but also by breed and individuality of the cow. Green feeds, as grasses, give the highest color, while dry feeds, as hay and grain, the least color. The Guernsey and Jersey breeds produce the highest colored milk and butter; the Holstein and Ayrshire the lightest colored. The yellow color of milk is often taken as an index of its richness, but this cannot be relied upon, and is of little value as a means of judging the quality of milk.

**V. Variation in Quantity and Quality.**

1. *Breed.*—Certain breeds of cows are characterized by producing rich milk, and others by producing unusually large quantities. The breeds that produce rich milk produce a less quantity, on the average, than do those producing the poorer quality. In order of *richness*, the common breeds stand as follows: Jersey, Guernsey, Short Horn, Red Poll, Ayrshire, Holstein. The Holstein breed stands considerably ahead in

FIG. 39.—A GUERNSEY COW—CHARMANTE OF THE GRON 14442. ADV. R. NO. 74.

Test, 11,874.76 pounds milk; 676 pounds fat. Florham Farms, New Jersey.

FIG. 40.—A JERSEY COW—IMP. JERSEY VENTURE 122508. A. J. C. C. 8285, J. H. B. F. S.

Lone Tree Herd, Greensburg, Ind.

*amount* of milk, followed by the Ayrshire, Guernsey, and Jersey.

2. *Individuality.*—The difference between individual animals in the same breed is greater than the average difference between breeds, both as to quality and quantity of milk produced. This factor should be given first consideration in estimating the value of an animal for dairy purposes.

3. *Period of Lactation.*—By period of lactation is meant one complete milking period, usually from nine months to one year. A cow, as a rule, produces the most milk per day within a month after the calf is born, and gradually decreases in amount until the secretion ceases. The lowest per cent. of butter fat usually is found at the time of greatest production, and increases somewhat as the flow of milk decreases.

4. *Feed.*—The kind and amount of feed have great influence on the quantity of milk produced, but have no effect on the per cent. of butter fat, although it is believed otherwise by many dairymen. The richness of a cow's milk is as natural to her as is the color of her hair, and is affected about as little by change of feed.

5. *External Conditions.*—Many other things affect the quality and the amount of milk secreted—as, treatment by milker, change of

FIG. 41.—AN AYRSHIRE COW—VIOLA DRUMMOND.

10,000 pounds of milk in 365 days; test, 3.9 per cent. fat. Riverside Stock Farm, Woodville, N. Y.

FIG. 42.—A HOLSTEIN COW.

Owned by M. E. Moore, Cameron, Mo.

weather, sudden fright, milking at irregular intervals, and sickness.

6. *First and Last Milk Drawn.*—The first milk drawn from the udder at any milking is much poorer in quality than the last. The first often tests as low as 1 to 1.5 per cent. fat, and the last 8 to 9 per cent. fat.

7. *Intervals between Milkings.*—When the intervals between milkings are equal in length, the morning and night milk is usually about the same in quantity and quality. When the intervals are not equal, the larger amount, but the lower per cent. fat, follows the longer interval. here 3rd

**IV. The Babcock Test.**

1. *Need of a Test for Butter Fat.*—Milk varies greatly in richness. The writer once tested the milk of a herd of cows each day for a year. The milk of one cow averaged 2.7 per cent. butter fat; that of another, 7 per cent. The variation in milk from different herds, although less extreme than the case mentioned, is found to be very marked; hence, to do justice to all, milk is now bought or sold at wholesale, as a rule, by the test.

The creamery or cheese factory pays a certain price for each pound of butter fat as ascertained by the test, and not for the gallon or hundredweight of milk. This does away with all temptation to milk adulteration by watering or skimming when selling by the test. Milk

sold at retail in cities is required in most places, either by state or city law, to contain not less than a certain per cent. of butter fat—usually 3 or 3.25 per cent.

*Problem.*—*A* owned a cow giving milk which averaged 2.7 per cent. butter fat. *B* owned a cow giving milk averaging 7 per cent. butter fat.

*C* bought one gallon (8.4 pounds) of milk of *A* daily, from March 1st to September 1st, at 6 cents a quart.

*D* bought milk of *B* for the same time, buying the same amount daily, at the same price per quart. If butter fat was worth 25 cents per pound at the creamery, how much did *D* gain by buying milk of *B* instead of *A* for the six months named? Did he pay more or less than the milk would have sold for by the test, supposing that a gallon of the milk weighed 8.4 pounds? How much?

Another and possibly the greatest value of the test is as a means of enabling the farmer to judge which cows are profitable and which are not. The writer once fed two Jersey cows standing side by side the same kind of feed and practically the same amount to each. During the year one produced 145 pounds of butter, the other 428 pounds.

The farmer should take into account not the per cent. of butter fat alone, but the amount of milk and the test together. The following is the record of two cows in the same herd:

| | *Pounds Milk* | *Pounds Butter* | *Per cent. Butter Fat* |
|---|---|---|---|
| No. 1............ | 12,111 | 538 | 3.81 |
| No. 2............ | 6,523 | 532 | 7.00 |

In this case it will be observed that the richness of the milk alone is not a fair means of judging the value of the two cows, neither is the amount of milk alone.

2. *The Babcock Method.*—The method generally used for finding the amount of butter fat in milk and its products is known as the Babcock test, and has done more to revolutionize the dairy industry than any other invention except the centrifugal cream separator. This method was invented by Dr. Babcock, of the Wisconsin Experiment Station, in 1890. It is an accurate, rapid method for finding the per cent. of butter fat in milk, cream, skim-milk, buttermilk, whey, or cheese. In this system sulphuric acid is used to dissolve the solids other than fat in milk, and the fat is then separated by centrifugal force, and measured on a graduated scale. The apparatus includes the following (Fig. 43): test-bottles, 17.6 centimeter pipette, acid measure, sulphuric acid, and a centrifugal machine (Fig. 44).

(1) TEST-BOTTLES. — The test-bottles are made of strong glass, to withstand sudden changes of temperature. On the neck is a scale graduated from 0 to 10. Each whole division represents 1 per cent., and is subdivided into five divisions, each one reading .2 per cent. By estimating between divisions, the reading of the test may be made to .1 per cent.

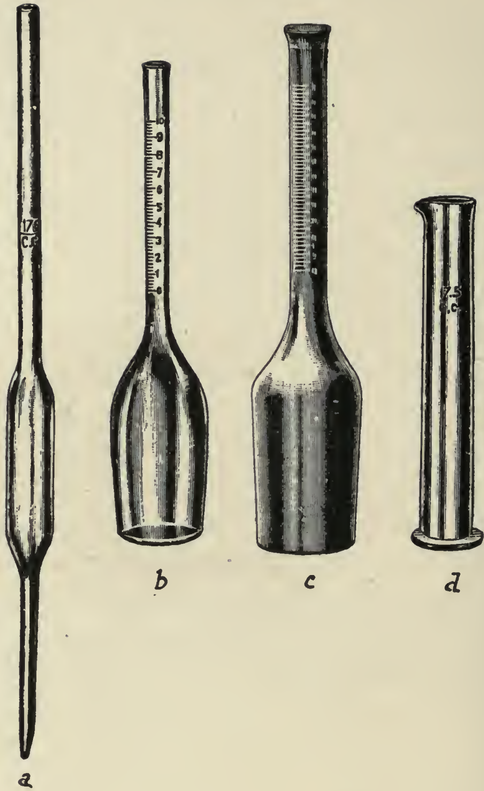



FIG. 43.—GLASSWARE FOR BABCOCK TESTER.

*a*—Measuring pipette. *b*—Milk-testing bottle. *c*—Cream-testing bottle. *d*—Acid measure.

(2) PIPETTE.—The basis of the test is 18 grams of milk. As a matter of convenience, the amount is measured and not weighed. It is found that a pipette holding 17.6 cubic centimeters to the mark delivers 18 grams of milk. The pipette is filled by suction of the lips, and

the top of the pipette closed with the forefinger.

(3) Acid Measure.—This holds 17.5 cubic centimeters, and is usually made in the form of a cylinder with a base.

The acid used is that known as commercial sulphuric acid, having a specific gravity of 1.81 to 1.83. If the acid be a little weak the fact will be known by white sediment appearing under the fat column, and this may be remedied by using a little more acid in another test. If the acid be too strong it will be indicated by the column of the fat being blackened and having black sediment below. This can be remedied by using somewhat less acid. Acid very much stronger or weaker than the standard does not give satisfactory results.

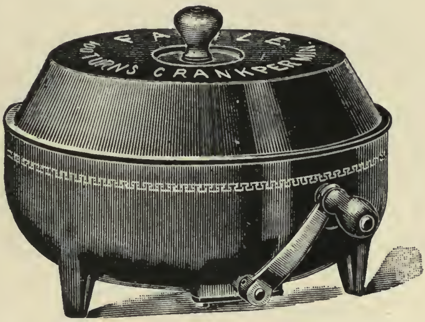


FIG. 44.—HAND-POWER BABCOCK TESTER.
This style is made especially for farm use.

(4) Centrifugal Machine.—Many forms of machines are made, varying in capacity from two to forty test-bottles. The smaller (Fig. 44) are made for use in small dairies, and run by hand; the larger ones are used in factory work,

and are run by steam-power. The bottles should always be arranged so that the machine will be balanced before running it.

The speed at which these machines are to be run depends upon the size of the revolving wheel, but the rim should, as a rule, move from 60 to 70 feet per second.

(5) Sampling Milk.—In testing milk the greatest care is necessary to get a fair sample of the lot to be tested. The entire amount should be poured from one vessel to another several times if possible, or, if this cannot be done, it should be stirred thoroughly from top to bottom. Many errors are made by not securing the correct average sample.

(6) Making the Test —(*a*) Mix the milk thoroughly, and measure sample into test-bottle. (*b*) Add measure of acid by pouring carefully down side of bottle held at slight angle from perpendicular.* (*c*) Mix thoroughly by shaking with a rotary motion until the liquid becomes an even chocolate brown color. (*d*) Run in a centrifugal machine five minutes at correct speed. (*e*) Stop and fill to base of neck with hot water or distilled water, 150° F. or above. (*f*) Whirl 3 minutes, then fill with hot water to 7 or 9 per cent. mark. (*g*) Whirl 2 minutes and make reading.

(7) Reading the Test.—Care must be taken to keep the contents of the test-bottle hot and the fat entirely liquid. It is at times necessary

* Care should be taken not to allow the acid to come in contact with the fingers or clothing.

to place the bottle in hot water between whirlings before making the reading. The reading of the fat column is taken from the extreme top to the extreme bottom.

(8) Testing Skim-milk and Buttermilk.—The operator of a butter or cheese factory should keep close watch on the losses of butter fat in the skim-milk and buttermilk by making frequent tests. For testing these products exactly the same method is used as described for testing milk, except a special kind of bottle, having two necks, is used, which allows finer readings to be made. Each small division on these bottles reads .05 of 1 per cent., and by estimating readings can be made to .01 of 1 per cent.

(9) Testing Cream.—It is far more difficult to make an accurate test of butter fat in cream than in milk. Cream varies greatly in amount of butter fat present, ranging from 12 or 15 per cent. to 60 per cent. of butter fat. As the milk test-bottle only reads to 10 per cent., it is necessary to have a special testing-bottle for cream where much testing is to be done.

Cream can be tested in ordinary milk test-bottles by adding two measures of water to one of cream, then testing the mixture in the same manner as for milk, multiplying the reading by three. When the common cream test-bottles are at hand which read to 30 per cent., the 17.6

milk pipette may be used and the testing carried out the same as with milk, except only about three-fourths the usual amount of acid is used.

If the cream has more than 30 per cent. of fat it cannot be read on the scale on the bottle. Under these circumstances one measure of cream and one of water may be mixed together, and a test made of the mixture, doubling the readings.

Weigh Out Cream for Testing.—The foregoing methods of testing cream are accurate enough for some purposes, but when cream is bought and sold by the per cent. of butter fat the amount of cream taken as a sample for testing should be *weighed* out and not measured. The measuring of cream introduces several errors which cannot be discussed in detail here, but all tend to make the result of the test too small. The chief error affecting accuracy of measuring cream is the difference in specific gravity of cream and milk. The 17.6 *c.c.* pipette delivers 18 grams of milk, but as cream is lighter than milk, does not deliver 18 grams of cream.

To avoid all these errors, small balancers are used, and 18 grams of cream weighed out into the test-bottle.

## *B.*—CREAM.

### I. Separation of Cream.

Cream is that portion of milk into which most of the fat globules have been gathered. It has the same constituents as milk, but in a different

proportion, due to the large amount of fat present.

Cream is separated from milk for food purposes, and as a matter of convenience and economy in making butter. Butter can be made, and is made in some countries, by churning milk. Cream may contain from 12 to 60 per cent. of butter fat. Cream as sold at retail usually has from 18 to 20 per cent., and a very rich cream has from 35 to 45 per cent. of fat. The apparent thickness of cream is not a reliable means of judging its real quality. Cream is separated from milk by taking advantage of the difference in specific gravity between the fat globules and the remainder of the milk. We have two general systems of separating cream. Both take advantage of the difference in specific gravity already mentioned.

1. *By Gravity.*—If milk be allowed to remain undisturbed in a vessel of any kind, the fat globules, being slightly lighter than the other constituents, gradually rise to the top. This is the oldest and, until recent years, the only method of separation in use.

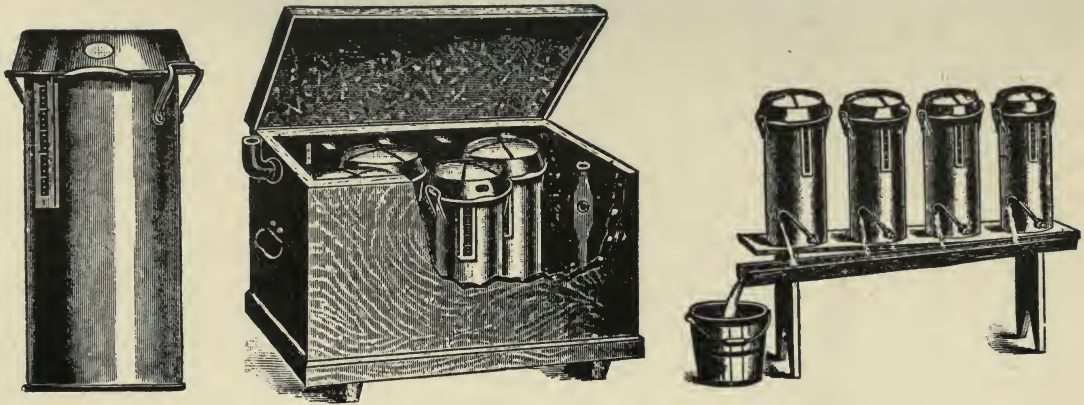
There are two methods of gravity creaming in common use: shallow pans, and deep setting.

(1) SHALLOW PANS.—Although the oldest and least effective in every way, this is still the most common method used in many localities. As generally used, the milk is placed in shallow

pans or crocks, kept at a rather low temperature, as in a cellar, until the cream has risen. It is then skimmed off with a flat skimmer.

The conditions most favorable for this system is a layer of milk not over four inches deep and cooled rapidly to a temperature of about 60° F., and allowed to stand 36 hours before skimming. This separation of the cream is not very complete by this method, and in this respect it ranks lowest of all systems used. On an average, about one-fourth of the butter fat is lost in the skim-milk when using the shallow pans. The quality of cream for butter-making purpose is also the poorest. On account of the large surface exposed to the air during the rising of the cream, any obnoxious odors of the atmosphere are readily absorbed, and this exposure also makes conditions favorable for the formation of strong, undesirable tastes in the cream and butter. Cream from this system is in condition for food purposes only when skimmed off much sooner than would be done when used for butter-making.

(2) Deep Setting.—The deep-setting system consists in placing the milk in cans about twenty inches deep and six inches in diameter (Fig. 45), set in water which should be kept at 40° F., or below, for twelve to twenty-four hours. At the end of this time skimming is done by using a conical dipper, or drawing off first the skim-



*A* *B* *C*

FIG. 45.—COOLEY CREAMER.

*A*—Deep-setting can used in Cooley creamer. *B*—Tank for setting cans in ice-water. *C*—Manner of skimming.

milk and then the cream from a faucet in the bottom of the can (Fig. 45). This system is in general use in some localities, and with general satisfaction. The deep setting ranks, both in thoroughness of separation and quality of cream for food and butter-making, next to the centrifugal separator. Under proper conditions, by its use 80 to 90 per cent. of the butter fat should be secured in the cream. The cream from this system is rather low in butter fat, as a rule testing from 18 to 20 per cent. fat.

(3) Dilution.—Within recent years an old plan of diluting milk with cold water has been revived, and devices for using this method have been sold very extensively in many places under the name of "water separators," "aquatic separators," etc. The general plan is to add cold water equal in volume to the milk. Instead of ranking with the cream separator, in whose name they are wrongfully given, they rank with the shallow pan in thoroughness of separation. As a rule, from 20 to 50 per cent. of the butter fat is lost in the skim-milk. The diluted condition of the skim-milk is another disadvantage. The quality of the cream is better than that of the shallow pan, and it is more convenient.

2. *By Centrifugal Force.*—The centrifugal separator (Fig. 46) has revolutionized the dairy industry within recent years. The first centri-

Introd. into N. Hampshire in 1884.

fugal separators were put in practical use in Europe about 1879, but were not in general use until ten years later.

At present they are considered indispensable

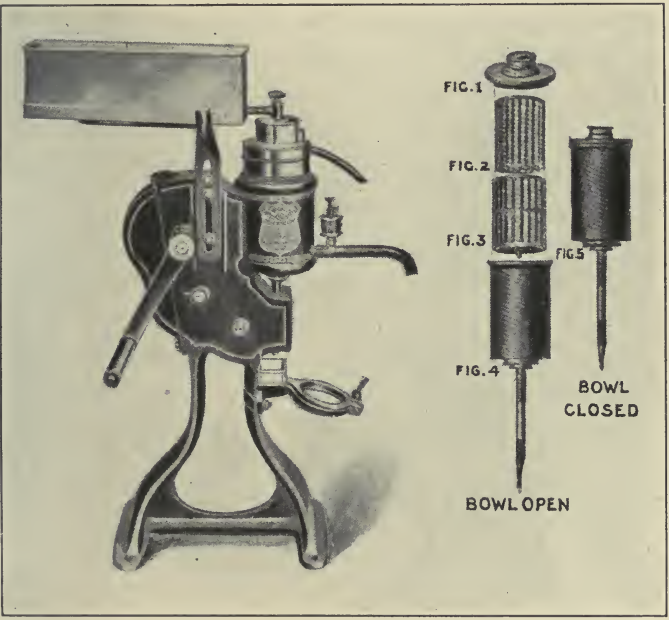



FIG. 46.—A MODERN HAND-POWER CREAM SEPARATOR.

This separator has a capacity of 450 pounds of milk per hour. The bowl on the right generates the centrifugal force by revolving rapidly.

to the successful dairyman. In the separator the centrifugal force generated by a rapidly revolving bowl takes the place of gravity and acts with a force very much greater. The milk flows into the revolving bowl (Fig. 46) in a continu-

ous stream, while the cream flows from one opening and the skim-milk from another.

As the milk flows into the revolving bowl, it is acted upon by centrifugal force, and flies to the outside wall of the bowl. The skim-milk, being heavier than the cream, is forced outward with greater force, and seeks the outside of the bowl, forcing the lighter cream toward the center. Near the outer edge of the bowl are openings of small tubes, into which the skim-milk flows and through them passes out of the bowl. Near the center of the bowl is the opening of a small tube, which carries out a constant stream of cream.

A number of conditions affect the thoroughness of separation with a centrifugal separator, especially the speed of machine, the temperature of milk, and the rate of inflow of milk. The most favorable temperature for separating milk is from 85° to 100° F. When the temperature falls much below 80°, the loss of butter fat with the skim-milk begins to increase. Some types of separators are much more sensitive to low temperature than are others.

The proportion of the milk taken out as cream can be changed in most separators without changing the thoroughness of separation by slightly turning what is called the cream screw. By this means most separators may be adjusted to separate from 10 to 50 per cent. of

butter fat. The centrifugal separator should remove about 98 per cent. of the butter fat in the form of cream. The cream from the separator, being removed while the milk is sweet, is in the best condition for food or for butter-making purposes. Separators vary in capacity from 150 to 4,000 pounds of milk per hour.

PROBLEM.—A farmer feeds to hogs 5 gallons (42.5 pounds) of skim-milk daily from June 1st to December 1st. What will be his loss, supposing that butter averaged 18 cents per pound, and he sells his hogs for $5.00 per hundred pounds, if he separated his cream by the gravity process—

(*a*) With shallow pans?

(*b*) With cans 20 inches deep?

(*c*) If he used the centrifugal separator?

(*d*) By which method of separation would he lose most, and how much more than by each of the other two methods?

**II. Ripening Cream.**

It is a well-known fact that milk which is allowed to stand in a warm place for a few hours begins to sour and finally coagulates. This is a process of fermentation, and is due to the growth of an immense number of living organisms called bacteria. These bacteria are not in the milk when it leaves the animal body, but gain access from many sources, such as unclean utensils and dust from the air.

The souring fermentation is undesirable in milk to be used for food, but is a necessary part

of making the best butter. The consumers of butter prefer that it have the peculiar taste which is characteristic of butter made from soured or fermented cream. Butter churned from sweet cream is insipid in flavor and is not desired by many; furthermore, it does not keep as well as that from soured cream. For these reasons cream is allowed to sour before being churned into butter. This condition is usually brought about within twenty-four hours or less by leaving the cream moderately warm, usually from 60° to 70°. The most approved method is to add what is called a starter, to cause the desired kind of souring to begin. This may be likened to the use of yeast in bread-making. When the proper condition of sourness is reached the cream is ready for churning. This stage is detected by taste and appearance, or in factory work by an accurate test. The condition may be described as a mild, sour taste, and a somewhat thickened or granular appearance of the cream.

## *C.*—BUTTER.

### I. Coloring Butter.

The natural color produced, when cows are on fresh grass, is the standard butter color. This shade should be maintained throughout the year, and this requires the use of artificial coloring part of the time. Coloring made for this purpose is a common article in the markets.

The best coloring used in butter is made from *annotto*, a vegetable product, and is entirely harmless. There can be no objection to coloring butter, as it deceives no one and pleases the eye of the consumer. Butter without artificial coloring is almost unsalable in most markets during the winter months. The coloring-matter is added to the cream before churning. The coloring-matter is dissolved in an oil which unites with the fat of the butter and does not color the buttermilk.

**II. Kinds of Churns.**

A large number of churns have been invented, but none is better suited for the small dairy than the common barrel churn (Fig. 47). Churns with dashes, or other means of agitating the cream violently, are objectionable, on account of loss in churning and effect upon the quality of butter.

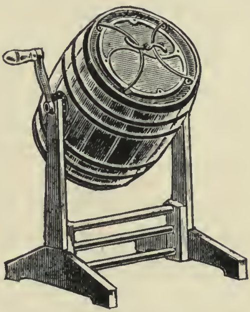


FIG. 47.—BARREL CHURN. Adapted for farm use.

Within recent years a new type of churn, called "combined churn and worker," has been put on the market. These churns are now used almost exclusively in large butter factories, and in many dairies. As the name indicates, this machine churns the cream, and later works the butter in the same apparatus.

**III. Churning.**

Churning is the gathering together of the fat globules into a mass called butter. This may be accomplished by any kind of agitation violent enough to cause the fat globules to come together with some force.

1. *Effect of Temperature.*—One of the most important factors to be considered in connection with churning is the temperature. Temperature controls, to a large extent, the time of churning, the loss of butter in the buttermilk, and that important quality of the butter called the grain. The higher the temperature of the cream the softer the butter fat becomes, and the more readily it unites, shortening the time of churning. The temperature should be so regulated that the time required for churning will be between one-half hour and one hour. No definite temperature can be given as applicable to all cases, as it must vary somewhat with the thickness of the cream, season of the year, and period of lactation. The best rule is to churn at as low a temperature as it is possible to have the butter form within the desired time. Butter factories, as a rule, churn cream from 50° to 54° F. in summer and from 54° to 58° in winter. (Smaller dairies usually churn at somewhat higher temperature.)

The greatest improvement that could be made at a small expense in the method of butter-making on the average farm would be the use

of a thermometer, and a proper control of the churning temperature. Butter churned too warm lacks firm texture, and is said to be "weak bodied" and softens easily in a warm temperature. Churning at too low a temperature results in unnecessarily lengthening the time of churning, with no advantage gained in the condition of the butter.

2. *Other Factors Affecting Time of Churning.*—The per cent. of butter fat has an important bearing upon the time of churning. A cream with a low per cent. of butter fat churns more slowly than does a richer cream, and requires a higher temperature. Cream from cows that have been giving milk a long time churns harder than cream from fresh cows, and requires a somewhat higher churning temperature, as the butter fat of the former is harder, the globules smaller, and the milk more viscid or sticky, making it more difficult for the fat globules to adhere together.

Cream from cows producing large fat globules churns a trifle easier than does that from those producing small ones, and may be churned at a lower temperature.

Cream produced from dry feed churns more slowly than that produced from green feed, and should be churned at a higher temperature, on account of the hardness of the fat and more viscid condition of the milk.

3. *When to Stop Churning.*—Churning should be stopped when the butter granules are about the size of large grains of wheat. Churning until the butter is gathered into a mass, as is often done, makes the removal of the buttermilk impossible, resulting in poor keeping quality and injured grain of the butter.

**IV. Washing Butter.**

When churning is completed and the buttermilk removed, the next thing to be done is to wash the butter. For this purpose clean, cold water, at a temperature somewhat colder than that at which the cream was churned, is used. About two-thirds as much water as there was cream is added to the butter, and the churn revolved slowly for six or eight turns. It is then stopped and the cold water drawn off. The object of washing is to remove the buttermilk from the butter.

**V. Salting.**

Butter is salted as a matter of taste. The amount of salt used may vary somewhat, but, as a rule, it is from three-quarters to seven-eighths of an ounce to each pound of butter. The salt used should be of the best quality, and made especially for this purpose. The act of mixing the salt with the butter is known as working the butter.

## VI. Working Butter.

The objects of working are to expel a portion of the water, to mix thoroughly the salt with the butter, and to get the butter into compact, marketable form (Fig. 48).

The combined churn and worker runs the butter between slowly revolving rollers, and is used almost exclusively in large butter factories. The working is continued until the salt is evenly distributed and the grain of the butter shows the right stage has been reached. At this stage the granules of butter almost lose their identity and string out slightly when the butter is broken, instead of breaking straight across. Overworking butter spoils its grain, and insufficient working results in uneven or streaked color of the butter, known as mottling. The latter is a very common and a very objectionable fault in butter.

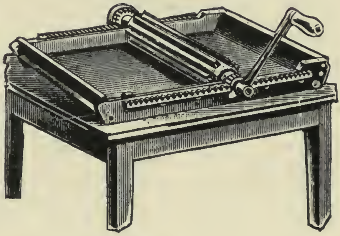


FIG. 48.—FARM DAIRY BUTTER-WORKER.
One of the best for farm use.

## VII. Composition of Butter.

The average composition of butter is about as follows: Fat, 85 per cent.; casein, 1 per cent.; salt, 2.5 per cent.; water, 11.5 per cent.

The composition varies considerably, especially the fat and water. Butter of good quality

seldom contains less than 80 per cent. of fat or more than 15 per cent. of water.

**VIII. Overrun.**

The term "overrun" is used to express the excess of butter made over the amount of butter fat contained in the cream or milk. The Babcock test shows the amount of pure butter fat. When this is made into butter, water, salt, and casein are present, in addition to the fat. Under the best conditions of handling, the butter should exceed the butter fat about one-sixth, but may vary greatly. The common method of estimating the yield of butter from the Babcock test is to find the total number of pounds of butter fat, and add one-sixth of its weight. This is the plan used by experiment stations and dairymen keeping records of the production of individual cows.

**IX. Packing and Marketing.**

After the butter is thoroughly worked, it is next packed in form for market. The style of package will vary with the market for which the product is intended.

When large quantities are to be shipped some distance, various sized tubs (holding from ten to sixty pounds) are used. These tubs are made of ash or spruce, and the sides are lined before use with a piece of parchment paper, a circle of the same being placed in the bottom of the tub and another on the top. For local sale, various

FIG. 49.—STUDENTS MOLDING AND WRAPPING BUTTER.

Missouri Agricultural Experiment Station.

packages are used—as, different sizes of wooden pails, glass or earthen jars, and paper boxes; but the one most favored is the rectangular pound print wrapped in parchment paper. These are made rapidly by means of molds designed for the purpose, and when once adjusted print very accurate pounds (Fig. 49).

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# OUTLINE OF CHAPTER IX.

## PROPAGATION OF PLANTS.

## *A.*—PROPAGATION FROM SEEDS.

### SEEDS AND SEEDLINGS.

**I. The Seed-coat.**

*Stratification.*

**II. The Testing of Seeds.**

1. *Importance of Seed-testing.*
2. *Purity.*
3. *Vitality.*

Factors influencing vitality are:

(1) Time of Gathering.

(2) Condition of Parent Plant.

(3) Age

(4) Method of Preservation.

**III. Germination of Seeds.**

A study of the conditions for germination:

1. *Temperature.*
2. *Moisture.*
3. *Air.*
4. *Geotropism.*
5. *Light.*
6. *Other Conditions.*

**IV. Treatment of Fine Seeds.**

**V. Variation of Plants.**

1. *Causes of Variation.*

(1) Difference in Food Supply

(2) Climatic Conditions.

(3) Sexual Reproduction.

2. *Fixation of Variation.*

(1) Means.

(*a*) Natural Selection.

(*b*) Artificial Selection.

(2) TIME DEPENDS UPON:
- (*a*) Tendency of the Plant to Vary.
- (*b*) Rate of Development.

## *B.*—PROPAGATION FROM BUDS.

### I. Cutting.

1. *Green Wood Cuttings.*
   - (1) LEAF CUTTINGS.
   - (2) STEM CUTTINGS.
2. *Hard-wood Cuttings.*
   - (1) STEM CUTTINGS.
   - (2) ROOT CUTTINGS.

### II. Budding.

1. *Spring Budding.*
2. *Late Summer or Early Fall Budding.*

### III. Grafting.

General principles of.
Subdivisions of.

1. *With Reference to Position of the Scion Upon the Stock.*
   - (1) ROOT-GRAFTING.
     - (*a*) Whole-root Grafting.
     - (*b*) Piece-root Grafting.
   - (2) STEM-GRAFTING.
     - (*a*) Top-grafting.
     - (*b*) Crown-grafting.
2. *With Reference to Insertion of Scion Into the Stock.*
   - (1) TONGUE OR WHIP GRAFT.
   - (2) CLEFT GRAFT.

### IV. Layering.

1. *Simple Layering.*
2. *Mound Layering.*
3. *Pot Layering.*

## *C.*—REFRENCES.

# CHAPTER IX.

## PROPAGATION OF PLANTS.

The basic principle of all horticultural operations is a thorough *knowledge of the plant and its environment.* This necessitates a careful study of the nature and conditions of the seedling throughout its development from the embryo to the adult plant.

### *A.*—PROPAGATION FROM SEEDS.

#### SEEDS AND SEEDLINGS.

**I. The Seed-coat.**

Examine the outer covering of a number of different seeds—as, the corn, bean, squash, peach, canna, and locust—noting carefully the difference in their textures. If these seeds be planted at the same time and under the same conditions, they will show equally as great variations in the time which they require for germination.

In nature, the hard, tough seeds of many orchard and forest trees—as, apple, peach, and hickory—are buried beneath the litter of the orchard or forest, where they are subjected to winter snows and changes of temperature until their outer coverings are softened or cracked, so that the embryonic plant may develop, while the seeds of such species as the catalpa (Fig. 50), honey-locust, and Kentucky coffee-bean re-

main on the trees all winter. This indicates that a cold, moist ground would be disastrous to them ; consequently, these seeds are shed in the warm days of spring, the higher temperature unsealing the waxy covering of the honey-locust, and the spring winds widely disseminating the delicately winged seeds of the catalpa. By following these hints of nature, man may perform and regulate these processes almost at will.

*Stratification* is a very practical and simple method of preparing many seeds having a hard or tough outer covering for germination. By this means the seeds are protected from mice, chipmunks, squirrels, etc., and at the same time given the conditions furnished by nature.

Directions for stratifying seeds: (*a*) In October or November take the seeds of cherry, apple, peach, plum, hickory, and walnut, which have been collected during the summer and autumn.

(*b*) Place, in a shallow box, a layer of sand, leaf-mould, or even garden soil, then a layer of the seeds; in this way alternate a layer of sand with one of seeds until the box is full.

(*c*) Sink the box in the ground in some shady place, and leave uncovered, exposed to the winter snows, rains, and frosts until the following spring.

(*d*) When the weather permits, plant thickly in rows in well-prepared soil. (See "Tillage.")

**II. The Testing of Seeds.**

1. *The Importance of Seed-testing* preparatory to planting, and the simple methods by which it may be done, are not generally realized.

FIG. 50.—CATALPA TREE.
Showing seed pods intact in February.

Often many annoyances and disappointments would be averted, and much time and labor saved, if proper attention were given to the quality of the seeds sown. Bad seeds not only result in partial or total failure of the crop, but may be the means of introducing noxious weeds—as, the plantains. A field is frequently sown in bracted plantain when it was meant to be sown in red clover. The principal points to be considered in determining the quality of seeds are *purity* and *vitality*.

2. *Purity.*—Various impurities may exist, either incidentally, or purposely, in commercial seeds—such as inert matter, or seeds of other useful or injurious plants—any of which would make the seeds more expensive if not altogether objectionable. Purity of seeds may be tested by carefully examining with the eye—or lens, if necessary—a fair sample of the seeds to be planted.

3. *Vitality of Seeds.*—In the testing of seeds it is not safe to rely upon general appearances—such as form, color, and odor—but the seeds must be actually tested to be certain of their vitality.

EXPERIMENT 15.—(*a*) From each kind of seeds desired, select at random a certain number, according to the quantity to be planted.

(*b*) If the seeds are large, it may be advantageous to soak them a few hours.

(*c*) Saturate several thicknesses of heavy blotting-paper, and fit them into shallow flats or plates; now place the seeds directly upon this moist paper. (If very fine seeds, put them upon squares of cheese-cloth spread upon the paper.) Cover the flats with pieces of window-glass, leaving crevices to admit air. Each day note carefully, and remove the number of seeds which sprout.

(*d*) What per cent. of seeds was vital? What does the *time* required for sprouting indicate regarding their vitality? Could the same results be expected from outdoor conditions? Would a farmer be justified in planting the seeds from which these samples were taken? Does not this test warrant the revision of the old adage, "Taste and try before you buy," to "Test and try before you buy," in this case?

Factors influencing the vitality of seeds are: (1) The time of gathering; (2) the condition of the parent plant; (3) the age of the seeds, and (4) the method of their preservation.

EXPERIMENT 16.—(*a*) Take seeds of several garden or farm crops—as, wheat, corn, beans, peas, radishes, lettuce, and apples—which have been gathered at intervals during the growing season, so that three stages (immaturity, maturity, and overripeness) in the development of the seeds may be represented.

(*b*) Note the date of gathering, the appearance of the seeds, and the condition of the parent plant at each of these three stages.

(*c*) Plant those of each stage in a separate row and label the rows.

(*d*) Observe, compare, and tabulate the time of appearance of each seedling.

(*e*) From your results in this experiment, what effect do you conclude the *time of gathering* has upon the vital-

ity of seeds? Why? What effect has the *condition of the parent plant* upon the vitality of the seeds?

(3) AGE OF SEEDS.—For the success of the following experiment time and patience are the chief requisites. The work may be begun in one class, and continued by each successive class as long as any of the seeds show vitality, or some student may elect this work throughout his school course.

EXPERIMENT 17.—(*a*) To make a careful and rather exhaustive study of the effect of age upon the vitality of seeds, two or three hundred of each kind of farm and garden seeds of the vicinity should be collected, each kind placed in a large-mouthed bottle, and labeled as to kind, date, and place of collection, and placed in a case provided for that purpose, together with a blank-book for a permanent record.

(*b*) Test each kind of seed according to Experiment 15, discarding any which do not show strong vitality, replacing them with new material as soon as possible, and relabeling.

(*c*) Repeat this test each successive year as long as any seeds show vitality.

(*d*) When any sample of seeds is no longer vital, discard the seeds and replace them with freshly tested ones, labeling as at first for the use of subsequent classes.

(*e*) Carefully note each year the *number* of seeds of each kind which germinate, and the time in hours required for their germination.

(*f*) What injuries may arise from retarded germination? Place your data in the permanent record, and compare with the data of previous years. This record

should eventually show the age at which the various kinds of seeds may be profitably planted.

(4) The Method of Preservation of seeds is of importance. Seeds should be freed from any pulpy material, carefully dried under moderate temperature, labeled with name and date, and stored in a cool, dry place which is absolutely mouse-proof.

## III. Germination of Seeds.

A study of the conditions necessary for the germination of seeds.

1. *Temperature.*

Experiment 18.—(*a*) Plant separate groups of similar, uniform-sized seeds of any garden or farm crop in jars or pots containing some moist pourous material—as, sawdust, sand, or moss.

(*b*) Place these jars in different parts of the building which have decidedly different temperatures—as, a north window, a south window, near a register, and in a basement.

(*c*) Record the temperature at each of these places each morning, noon, and night.

(*d*) Note the time of the appearance of each group of seedlings, and determine the time required for germination.

(*e*) Record the data thus obtained in tabular form.

(*f*) Compare. What does the experiment teach?

2. *Moisture*—Soaking seeds: effect of upon germination.

Experiment 19.—(*a*) Select a given number of seeds of various kinds—as, corn, wheat, beans, squash, and tomato.

(*b*) Divide each kind into two lots. Plant one of these

lots (each kind at the proper depth) in a box of sand; the other lot place in a shallow dish of water, and soak for ten or twelve hours; then plant these seeds in the sand at the same depth and under the same conditions as the first lot.

(*c*) Note and tabulate the time of the appearance of the seedlings of the soaked and unsoaked seeds of each kind.

(*d*) Was the time of germination of each kind shortened by the soaking? Were any seeds damaged by soaking?

EXPERIMENT 20.—(*a*) Select seeds, as in the above experiment. Soak one-half of each kind, as before.

(*b*) Now separate the soaked and the unsoaked seeds each into three lots.

(*c*) Plant one lot of each (the soaked and unsoaked) in dry soil, another in moist soil, and the third in *wet* soil, other conditions being the same for each.

(*d*) Tabulate, and compare results.

(*e*) What does this experiment teach concerning the condition of the soil with regard to moisture at the time of planting seeds?

3. *Air.*

EXPERIMENT 21.—(*a*) Fill a pot with *moist* sand or mellow garden soil, and another pot with clay or loam that has been *wet* and well stirred until about the consistency of paste. Now plant in each pot several beans, peas, or grains of corn, pressing them in and carefully *smoothing over* the top.

(*b*) Place both pots under the same external conditions. If the puddle clay or loam cracks, moisten it, and again press the surface smooth.

(*c*) Observe and note results. What fills the interstices in the jar of moist sand or soil? What in the puddled clay? Do the seeds in each pot germinate

equally well? Why? What condition is present in one pot that is not in the other?

4. *Geotropism.*

EXPERIMENT 22.—(*a*) Plant in moist sand or sawdust a number of squash seeds and grains of corn in various positions—some with either side down, some with either edge down, and some with either end down.

(*b*) Label each group as to position in planting.

(*c*) After two or three days, examine to see if any of the seeds have sprouted.

(*d*) If so, note carefully the direction of radicle and of plumule.‡ Draw.

(*e*) Label according to position, and name all parts.

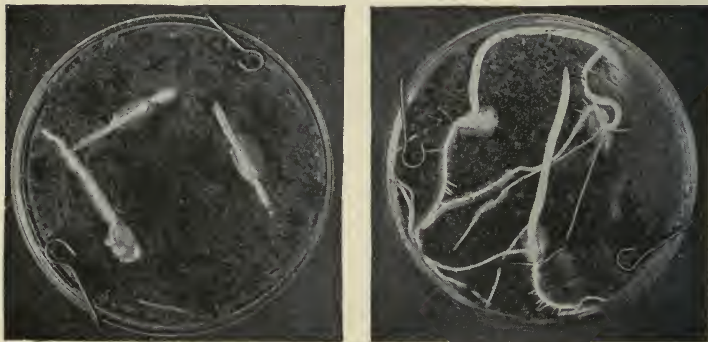
(*f*) Now plant again, with the position of the seed reversed. Repeat daily (*d*), (*e*), and (*f*) for several days.

(*g*) Does the position of the seed when planted have any effect upon the development of the embryo? Explain. How do the results of your daily observations compare with reference to the direction of growth of radicle and plumule?*

EXPERIMENT 23.—Stevens' "Introduction to Botany" gives the following experiment in connection with geotropism: "Remove the glass front and the hands from a cheap alarm-clock. Provide a soft pine block about an inch square, whittle one end to a taper, and drill a small hole into it, so that it will slip through the opening of the dial face and tightly over the hour-hand spindle. Fasten a Petri dish to the outer face of the pine block by a melted mixture of one-third beeswax and two-thirds rosin, taking care to center the dish with the hour-hand spindle. Pack moist pine sawdust into the dish level with the surface, and press soaked grains of corn into the sawdust, not very tightly, broad face down, but do not cover them with sawdust. Put on the cover

* For parts of seed and seedling, see any good *Botany*.

of the Petri dish and hold it in position by means of clips made of spring brass wire (Figs. 51, 52). (See Stevens' "Botany," p. 25.) Wind the clock, and set it in its normal position—that is, with the hour-hand spindle



From Stevens' "Introduction to Botany." Copyright, 1902, by D. C. Heath & Co.

FIGS. 51 AND 52.—SEEDLINGS OF INDIAN CORN

Grown in sawdust in a Petri dish while revolving by clockwork one revolution per hour. The axis of revolution is horizontal, the plane of the dish vertical. Gravity as a directive agent is eliminated, and roots and shoots grow out in the direction in which they happen to be pointed.

Grown in sawdust in a Petri dish which was kept stationary in a vertical position. Gravity is acting as a directive agent, and the roots find and take the downward and the shoots the upward direction, irrespective of the directions toward which they were originally pointing.

horizontal. Prepare seeds in another dish in exactly the same manner, but fasten it so that it will stand vertically on its edge.

In the first experiment the directive effect of gravity would be neutralized by the revolution of the dish, while in the second gravity may exercise its usual influence on the direction taken by root and shoot. Compare results as to direction of radicle and plumule.*

* Since the seeds are not covered by the sawdust, their progress in germination may be observed at any time without interrupting the experiment. The position occupied by the parts of the seedlings can easily be recorded for any period by tracing with ink on the cover immediately over them.

5. *Light.*

EXPERIMENT 24.—(*a*) Soak a number of different kinds of seeds for a few hours and divide each kind into lots.

(*b*) Place each lot on a square of moist flannel laid upon moist sand, and cover with a glass tumbler.

(*c*) Now cover one of these tumblers with a heavy paper cone, the inside of which has been blackened by simply holding it over a lighted lamp.

(*d*) Watch the seeds in the uncovered tumbler. As soon as any growth is shown, remove the paper cone from the other tumbler, and compare the growth made in the dark with that made in the light for each kind of seeds.

(*e*) *Is light a necessary condition for germination?*

6. *Other Conditions.*

EXPERIMENT 25.—(*a*) Soak for a few hours a number of peas and Lima beans. Plant a definite number of each kind of these soaked seeds at the same time in moist sand at various depths, from one-half inch to four inches, labeling as to depth.

(*b*) Note carefully the appearance of each kind of seedlings planted at the *various depths.*

(*c*) Within a few days after the appearance of the first seedlings, observe (1) the growth made by the peas planted at the various depths, and compare; (2) that made by the beans at the various depths; (3) the relative growth made by the peas and beans.

(*d*) Does the *depth* of planting have any effect upon the *time* of germination? Upon the *certainty* of germination? By what external conditions is the germination influenced? What relation does the development of the seedlings themselves bear to the depth of planting?

## IV. Treatment of Fine Seeds.

Where practicable, very small seeds should be sown indoors and given special care.

Directions: For this purpose, use shallow boxes—about four inches in depth—which have been soaked in lime-water, or water containing a little formaldehyde, or whitewashed.

(*a*) Fill these with a soil prepared by carefully mixing equal parts of sand and leaf-mould, or rotted sod cut up fine and sifted. It is well to add to this a very small quantity of wood ashes. Sow the seeds on the surface of the soil and press them in.

(*b*) Apply moisture by very lightly sprinkling with a small sprinkler or by hand. Cover with window-glass, providing for the admission of air.

(*c*) As soon as true leaves are well formed, they may be transplanted into inch pots, and repotted into larger-sized pots as often as is necessary. Before planting in the open ground the plants should be hardened in a cold frame (see under "Cuttings").

### V. Variation of Plants.

Though the offspring of plants is like the parent in kind, yet individual members of the species are not *exactly* alike. Their differences are often scarcely perceptible; but if various members of the same species in a given locality be compared, shades of differences may be seen. For example, the little spring beauty (*Clatonia virginica*) shows much variation in the number and size of its petals. Their color also ranges from white to deep pink. The dog's-tooth violet (*Erythronium albidum*) shows like morphological differences.

Throughout nature these variations exist, the offspring differing from its progenitor. Among

FIG. 53.—RED FIR.
Near the timber line Mount Baldy. Elevation, 9,000 feet.

FIG. 54.—RED FIR.
Foot of Mount Baldy. Elevation, 4 700 feet.

the higher plants those species covering a wide range show greater variation in their individual members than species more restricted in their distribution—conditions which might be expected: the more diverse the environment, the more variable the individual. Thus, the luxuriantly growing plant at the base of a mountain varies greatly from its dwarfed brother at the summit (Figs. 53, 54). On the other hand, the more variable the plant the more easily it can adapt itself to varying conditions; hence, the more widely it is distributed.

1. *Causes of Variation.*—Variation is not the result of chance, yet the detailed differences in varieties of the same species can only be suggested.

In every individual two factors are manifest: the nature of the organism, and the nature of the external conditions. Nevertheless, the same conditions do not always produce the same results, for similar varieties may be "produced* from the same species under external conditions of life as different as can well be conceived, and, on the other hand, dissimilar varieties may be produced under apparently the same conditions." Variation, then, may be due, for the most part, to the innate tendency of the organism to vary, the causes of which are not fully understood. However, some of the causes of

* Darwin's *Origin of Species*, p. 127.

*variation* among plants seem to be: (1) difference in food supply; (2) climatic conditions; (3) sexual reproduction.

None of these causes would be of any avail were it not for the fact that *selection* preserves and accumulates all variations which are beneficial, and discards those which are detrimental to the organism.

(1) DIFFERENCE IN FOOD SUPPLY.—Every one has noticed in different fields of grain, or even in the same field, that in some portion the plants were sickly and stunted, while in others they were strong and well developed. One of the many conditions which may cause *this variation* (in development) is a difference in the supply of proper food.

This lack of the necessary constituents for the growth of this particular plant may be due to the exhaustion of these elements by former crops, or to the poorness or thinness of the soil. (See Chapter VII.)

(2) CLIMATIC CONDITIONS.—Variation in climate tends to modify the structure and habits of plants, their fruitfulness, and the color and flavor of their fruit. On approaching colder climates plants become smaller and more thickly set with leaves, as is illustrated by the same species growing at the base and at the summit of a mountain (Figs. 53, 54), as the spruce and fir of the Rockies.

here 3rd

(3) Sexual Reproduction is probably the most important of the causes of variation in plants. This is exemplified by those lower forms which usually reproduce asexually, since they show very little variation in many generations. On the contrary, among higher plants, where reproduction is ordinarily sexual, the offspring may vary greatly in one generation. (Thus, a field planted in white or yellow corn may produce many variously colored ears.) Hundreds of examples of both wild and cultivated plants may be given.*

This variation is due, in a great measure, to the fact that each organism is the product of two separate elements the male and the female. And each of these was itself a product of two separate elements. In this way the whole ancestral line was developed. These characteristic differences are the more marked when the male and the female elements are derived from different individuals; for in the offspring is made possible any of the characteristics, not only of the immediate parents, but of the entire ancestry of each. Thus, cross-fertilization becomes a potent factor in producing variation.

2. *Fixation of Variation.*—When variations are *beneficial* to the plant in its present environ-

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* "No case is on record of a variable organism ceasing to vary under cultivation. Our oldest cultivated plants, such as wheat, still yield new varieties."—*Origin of Species*, Darwin, p. 6.

ment, *Natural Selection* preserves and accumulates them; when they are *not* beneficial, Natural Selection discards them; that is, *the plant possessing these beneficial variations has a better chance to survive and perpetuate the species, while the plant whose variations are less beneficial will probably perish; hence, that variation is not perpetuated.*

Everywhere in nature the competent are preserved and the incompetent are discarded. In other words, the power of an organism to vary is the measure of its adaptability to environment. It is by the preservation, transmission, and accumulation of these variations that new varieties are formed among uncultivated plants. Man takes advantage of this fact, and by *artificial selection* preserves those characteristics of the plant which are beneficial *to him*, thus originating new varieties among cultivated plants.

It takes many generations for these varieties to become fixed types. The time required for the fixation of types, however, depends upon several conditions, one of which is (1) the tendency of the plant to vary. The more variable the plant, the more difficult will be the fixation of the type; for, although it will be easier to find individual plants having the desired characteristics, on account of this variability there will be less assurance that these characteristics will be generally reproduced in the subsequent

generations. Common examples of this tendency to vary are the grape and the potato.

Another condition is (2) the *time* required for the growth of a plant from the seed to the maturity of its seed. Many species require but a

FIG. 55.—ROOTED TIPS OF A SEEDLING RASPBERRY CANE.

They are of one season's growth, showing new plants formed and their root-systems. (From Normal Garden.)

single season; most trees require a number of years to produce one generation. Four years from seed to seed would be a short period for apple, pear, and cherry, and some varieties require a much longer time.

Hence, it would be impracticable, if not impossible, in the lifetime of one man, to render

the desired characteristics of these plants permanent—that is, by the selection and reproduction of the seedling. So in these cases the factor of sexual reproduction must be eliminated, and thus the tendency of the plant to vary less-

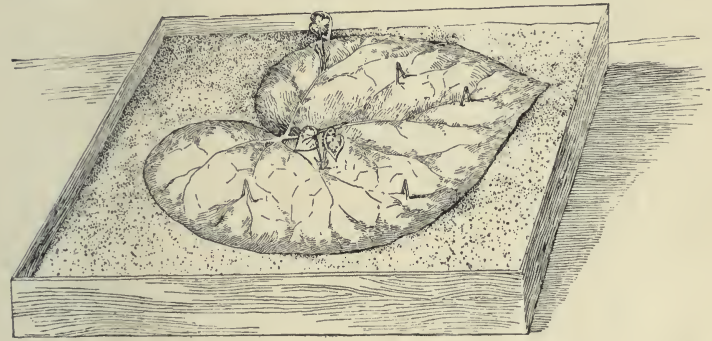


FIG. 56.—LEAF CUTTING—WHOLE LEAF.

ened, if one would perpetuate the variety. This is done by the *propagation of plants from buds, or asexual reproduction.*

## *B.*—PROPAGATION FROM BUDS.

Here, again, nature gives us examples among the uncultivated plants. The wild strawberry multiplies asexually by throwing out runners which form roots and become new plants. The raspberry bends its flexible branches until their tips touch the moist earth; soon they are covered by leaf-mould or soil, and new plants are formed by sending out roots from these buried tips.

Many other examples of asexual reproduction may be found—as, rootstocks, tubers, bulbs, etc.

Bud propagation may be carried on by four different processes : cutting, budding, grafting, and layering, according to (1) the number of buds used, (2) the condition of the material, and (3) the season of the year in which the work is done, as is shown by the following scheme :

| | CUTTING. | BUDDING. | GRAFTING. | LAYERING. |
|---|---|---|---|---|
| Number of Buds. | One to several. | One. | Two or more. | One to several. |
| Time of year. | Throughout the year, except in hot weather. | Early and late summer. | Last month of winter, or second month of spring. | Spring and summer. |
| Condition of material. | Either dormant or growing. | Growing. | Scion, dormant.<br>Stock { Dormant or Growing. | Growing. |

begin here

## I. Cutting.

This process consists in taking a leaf, a portion of a stem, or of a root, and placing it in such conditions that adventitious roots are formed, and thus it becomes a new plant.

1. *Green Wood Cuttings* are made from the green parts of a growing plant. To secure the best results, the cuttings should be taken from a well-matured branch of a vigorous, healthy plant.

FIG. 57.—LEAF CUTTING—PART OF LEAF.

FIG. 58.—LEAF CUTTING OF *Sansevieria zeylanica*.

(1) LEAF CUTTINGS (~~Fig. 56~~).—There are few plants which can be grown from leaves; among these are the *Sansevieria ~~zeylanica~~* and begonia. Fleshy leaves most readily respond to this manner of propagation. The leaves may be placed upon moist sand and pegged down at the main veins, or the base of the leaf buried in the sand. Roots are thrown out at the *cut ends* of the veins, and new plants are formed at these points (~~Figs. 56, 57, 58~~).

(2) STEM CUTTINGS.—Directions for propagating by means of stem cuttings: (*a*) Cut thrifty shoots from different species of plants—as, geranium, coleus, ageratum, heliotrope, verbena, tomato, nasturtium, etc.

(*b*) Divide each of these shoots into cuttings, having at least two nodes each. In doing this begin with the top of the shoot, taking off a portion having two or more nodes, cutting through the stem immediately below the lower node. Reduce the leaf surface one-half (to check

FIG. 59.—TIP CUTTING OF A CHRYSANTHEMUM.

FIG. 60.—CUTTING OF HELIOTROPE.

evaporation) by removing the entire leaves from the lower portion, and, if need be, clipping some of the remaining leaves ~~(Figs. 59, 60)~~. One or more cuttings may be made from the remainder of the shoot. These are prepared like the tip cutting, with the exception that about one-half inch of stem should be allowed to project above the upper node.

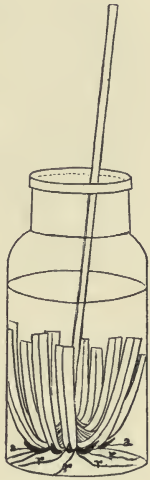
(*c*) As soon as each cutting is finished, it should be thrown into cold water.

(*a*) Fill the propagating-table* to the depth of four

*In absence of propagating-table, use a shallow box four or five inches deep ~~(Fig. 65)~~.

or five inches with clean, coarse sand. (Other conditions for starting cuttings should be the same as for seed germination.) If the cuttings are made in summer, the propagating-table will not require artificial heat; otherwise bottom heat must be supplied. In green-

FIG. 61.—CUTTING OF OLEANDER ROOTING IN WATER



*a*—Young shoots. *r*—Roots.

FIG. 62.—STEM CUTTING OF UMBRELLA PLANT ROOTING IN WATER.

houses, or buildings where the heat is sufficiently well regulated, this may be supplied by steam-pipes. Where this is not practicable, an excellent substitute may be furnished by the use of fermenting stable compost. The fresh compost should be mixed with a small proportion of straw and leaves, moistened and packed in an ample box, to the depth of about eighteen inches. Now spread upon this mixture about five inches of sand. (The box should be protected from direct sunlight and drafts.)

FIG. 63.—REMOVING A PLANT FROM A POT.

FIG. 64.—THE PLANT REMOVED FROM THE POT.

(*e*) Place a thermometer in the sand, and record the temperature at various intervals for several days. It will be evident that as the compost becomes heated the temperature will be too high for the cuttings, and they should not be put in until the temperature has fallen to about 80°.

(*f*) The cuttings should be well firmed in the sand to about one-half of their length, and placed about an inch apart in rows. After the cuttings are placed, brush the hand across their tops, to see if they are sufficiently well firmed. If so, none of them will be displaced. Label each species of cuttings with name and date.

(*g*) The sand must be kept uniformly moist, not wet. The cuttings may be carefully lifted out and examined from time to time, to see if any have rooted. The time required for each species to root should be recorded.

(*h*) As soon as the roots are about an inch long, the cuttings should be potted off into thumb-pots filled with soil prepared, as directed for treatment of fine seeds (page 212). These little pots should be sunk to one-third of their depth in flats of moist sand. As soon as the plant has grown until the pot is filled with roots, it should be transferred to a size larger pot.

(*i*) To ascertain whether the pot is filled with roots invert the pot, resting it upon the palm of the left hand, allowing the plant to pass between the fingers, and steadying the pot by placing the right hand upon the bottom. Now gently tap the edge of the pot against a box or table (Fig. 63) until the ball of soil drops into the hand (Fig. 64). As the plant continues to grow, repot in this manner as often as is necessary.

2. *Hard Wood Cuttings.*—(1) Stem Cuttings are taken from dormant, mature wood of the last season's growth. These may be secured any time after the leaves have fallen. In local-

FIG. 61. CHILDREN POTTING PLANTS. (KIRKSVILLE STATE NORMAL SCHOOL.)

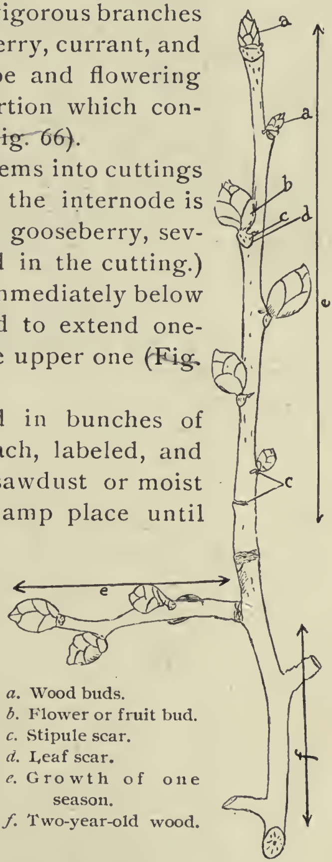
ities where the winter is severe, it is best to take the cutting before cold weather.

Directions for making hard wood cuttings: (*a*) For this purpose, select the most vigorous branches of such plants as the gooseberry, currant, and many varieties of the grape and flowering shrubs, and cut off that portion which consists of last year's growth (~~Fig. 66~~).

(*b*) Divide each of these stems into cuttings of at least two nodes. (If the internode is short, as in the currant and gooseberry, several nodes may be included in the cutting.) The stem should be cut off immediately below the lower node and allowed to extend one-fourth of an inch above the upper one (~~Fig. 69~~).

(*c*) These should be tied in bunches of from twenty-five to fifty each, labeled, and packed in boxes of green sawdust or moist sand, and kept in a cool, damp place until spring.

(*d*) The cuttings may be started in a propagating-box (~~see page 226~~) or hot-bed as early as February or March, and transferred to the open ground as soon as the weather permits. Where this is not practicable, they may remain packed in the sawdust until favorable weather, and placed at once in the open ground, which has been prepared by deep plowing and thorough pulverizing.




*a*. Wood buds.
*b*. Flower or fruit bud.
*c*. Stipule scar.
*d*. Leaf scar.
*e*. Growth of one season.
*f*. Two-year-old wood.

FIG. 66.—TWIG OF WHITE ELM (*Ulmus Americana*, L.)

(*e*) Plant them in an oblique position, leaving the upper node above the surface (Fig. 67), and two or three inches apart in rows four feet apart. The soil should be closely pressed about the base of the cuttings to prevent their drying out. They should be frequently cultivated throughout the growing season.

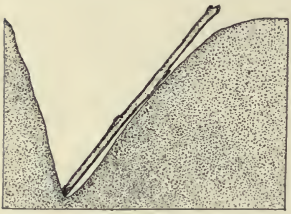


FIG. 67.—POSITION OF HARD-WOOD CUTTING IN SOIL.

(*f*) Some of them may have made sufficient growth (Fig. 68) the first season to justify their being transplanted to the grounds where they are to remain.

(2) ROOT CUTTINGS.—All species of plants which "sprout from the roots" may be propagated by means of root cuttings In some cases these cuttings are really portions of underground stems—as, horseradish, rhubarb, etc. But cuttings from real roots have no buds, as those of the blackberry and quince ~~(Fig. 70)~~.

FIG. 68.—ROOTED GRAPE CUTTING.

Directions for root-cuttings: (*a*) The roots should be cut into pieces two or three inches long. Most of them thrive best when started with bottom heat.

(*b*) Plant horizontally, close together, and entirely cover with two or three inches of soil.

## II. Budding.*

To propagate a plant by budding is to take a mature bud from the plant which one *desires to perpetuate*, and to

FIG. 70.—CUTTING OF BLACKBERRY ROOT.

insert it in the bark of some allied plant in which it develops. This must be done when the bark will peel easily and mature buds can be procured, the time of which will depend entirely upon the season. In general, there

FIG. 69. GRAPE CUTTING.

* Suggestion to teacher: The work of *budding* should be studied at the time of year when the required conditions are present in nature.

If, however, the school is not in session at this time, willow switches in which the growth has been started by standing in water in a sunny window for several weeks may be used as stocks, just to teach the students *how* to perform the operations of budding.

are two periods of the year in which budding may be done—spring and early fall.

1. *Spring budding.*—Directions for the work: (*a*) The strongest twigs of last year's growth should be carefully selected from the healthiest, best developed tree of the desired variety. These should be cut while dormant, packed in small boxes of green sawdust or moist sand, and kept in a cool, damp place until the stock‡ is in condition for inserting the buds.

FIG. 71.—THE WAY TO REMOVE A BUD.

(*b*) The stocks best suited for this work are well-developed one-year-old seedlings (Fig. 72). The stocks are prepared for the bud by making two incisions in the bark, one immediately above and at right angles to the other, forming a T-shaped cut (Fig. 73). These incisions should be made on the north side of the seedlings, away from the direct rays of the sun and close to the ground.

(*c*) Select mature wood-buds from that portion of the budding-stick‡ which is neither too old nor too young. Now place the knife one-fourth inch below the bud, cut through into the wood, and pass the knife upward beneath the bud to a point one-fourth inch above it. Remove the knife. Make a horizontal incision *just through* the bark at this upper point (Fig. 71). Now lift the edge of the bark, and carefully peel it back with the thumb and finger, leaving the *wood attached* to the budding-stick. Look on the under side of the bud, to see if it is hollow. If so, discard it, for the vascular bundles have been removed in preparing the bud, and it is worthless, for there is nothing left which will unite with the cambium layer of the stock (Fig. 73).

(*d*) Now turn back the edges of the bark in the **T**-shaped incision of the stock and insert the bud, as in Fig. 73, pushing it down until the top edge of the bark

FIG. 72.—ONE-YEAR-OLD PEACH SEEDLINGS.
(From Normal School Garden.)

is fitted in below the edge of the horizontal incision of the stock. Wrap with moist raffia‡ above and below the bud, so as to bring the parts into close contact.

(*e*) As soon as the bud unites with the stock—about ten days—the raffia should be cut, so as not to interfere with the growth of the bud. At the same time, the seedling should be cut back by removing the upper por-

tion an inch or two above the bud, so as to direct the growth of the plant to the new bud.

2. *In late summer or early fall budding* the process is the same as that of spring budding, *except* in this case

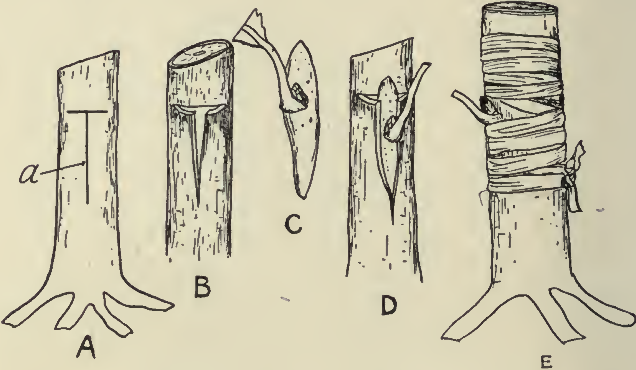



FIG. 73.—STAGES IN BUDDING.

*A*. T-shaped incision. *B*. Ready to receive the bud. *C*. The bud. *D*. Inserting the bud. *E*. Inserted and wrapped.

the leaves are present, and should be removed as soon as the scion is cut, leaving a portion of the petiole intact.

**III. Grafting.**

*Points which must not be overlooked* to secure a successful graft: (1) The cambium layer of the scion *must coincide* with that of the stock at least in one point, so that the sap may flow uninterruptedly; this will be the more certainly effected if all the cuts and incisions be made smoothly with a *sharp* knife.

(2) A moderate pressure must be provided, so that union may take place.

(3) All exposed cut surfaces must be protected from atmospheric agencies.

Grafting is divided *with reference to the position of the scion upon the stock* into (1) root-grafting, and (2) stem-grafting.

(1) Root-grafting. — For this purpose the roots of seedlings—most commonly, apples—from one to two years old should be used as stocks. The work should be done at least six or eight weeks before the time of planting.

(*a*) In whole-root grafting, the entire primary root is used, while in (*b*) piece-root grafting, pieces of the primary root, three or four inches long, are used. Thus, one primary root may furnish material for two or three grafts.

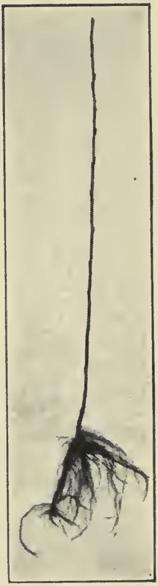


FIG. 74.—ONE-YEAR-OLD PIECE-ROOT GRAFT. The large mass of roots formed from the base of the scion. (From Normal Garden.)

Grafting is divided, with reference to the *method of insertion* of the scion into the stock, into (1) tongue or whip grafting, and (2) cleft-grafting. The tongue or whip graft is used for both piece and whole root grafting.

Directions for root-grafting: (*a*) Hold the stock or scion which is to be cut in the left hand, with the end supported by the index finger.

(*b*) Now make a diagonal cut through the base of the scion or the top of the stock, as the case may be. While still holding it in this position, beginning one-third of the length from the outer end of this cut, make a vertical slit about an inch long.

(*c*) When the stock and scion are each thus prepared,

FIG. 75.—STEPS IN ROOT-GRAFTING.

carefully insert the tongue of the one into the slit of the other in such a manner as to bring the cambium layer of the stock into direct contact with that of the scion (Fig. 75), and wrap closely with No. 18 knitting cotton or moist raffia.

(*d*) Cut this wrapping into foot lengths, and, beginning at one end of the grafted parts, pass the thread several times around, allowing one end of the thread to *be held beneath this wrapping*. Now pass the thread on up to the other end of the graft, and wrap again, this time fastening the free end of the thread by slipping it firmly between the projecting and the united parts of the graft, as in Fig. 75. This grafted stock when completed should be about eight or ten inches long.

(*e*) The whole root-grafts are made in exactly the same way, the whole primary root, of course, being used as the stock.

(*f*) These grafted stocks should now be tied in bundles and packed in green sawdust, or moist sand, until the weather is suitable for them to be planted in the open ground. The ground should be prepared for them by very deep plowing and thorough pulverizing.

(*g*) These root-grafts should be planted about six inches apart in rows four feet apart. Pains should be taken to *press the soil closely about* the roots, allowing but one bud to remain above the surface.

As a rule, they should be allowed to grow two years before being transplanted to the orchard, during which time clean cultivation should be given throughout the growing seasons.

(2) STEM-GRAFTING.—In stem-grafting, old or otherwise undesirable trees are used as stocks.

(*a*) Top-grafting.—The *method* of grafting used most often in this work is the cleft-graft, on account of the large size of the stocks to be grafted. For good results, however, the branches used as stocks should not be much over one and one-half inches in diameter.

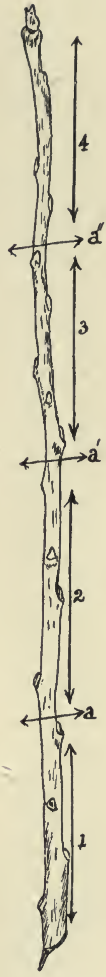



FIG. 76.—DORMANT APPLE TWIG.

1, 2, 3, 4 are scions which may be cut at the points a, a′, a″, respectively.

It would be too great a shock to the tree to remove all of the old top in one season; consequently, a portion of it should be grafted each

successive season, for three or four seasons, until the entire old top has been replaced.

Directions for top-grafting: (*a*) Time. This work should be done in the spring, just before, or about the time, the buds open, or even later, *provided* the scions can be kept dormant, as in root-grafting.

(*b*) The stock is prepared by making a smooth, hori-

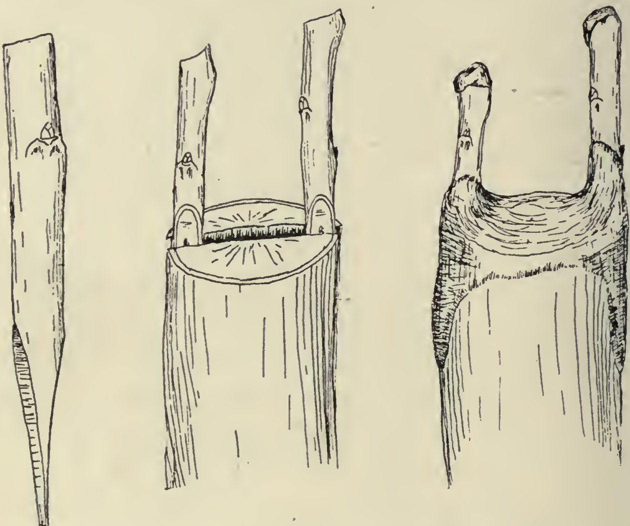


FIG. 77.—STEPS IN STEM-GRAFTING.

zontal cut through the stem. A vertical slit about an inch and one-half in length is now made down through the center (Fig. 77).

(*c*) The scion is prepared by making two diagonal cuts across the lower end, one on the opposite side of the stem from the other, so as to form a wedge-shaped point (Fig. 77).

(*d*) Since it doubles the chances of growth, two scions should be inserted in each cleft, inclining them at a slight

angle, so as to insure, at least at the point of intersection, the close contact of the cambium layers (Fig. 77).

(*e*) *All exposed cut surfaces should be carefully waxed, to keep out air and moisture.*

Grafting-wax is made by breaking into small pieces two to two and one-half parts (by weight) beeswax and four to five parts resin, and melting them together with one part of tallow or linseed oil. The greater the proportion of resin and beeswax, the harder the grafting-wax will be. When this mixture is *melted*, pour it into cold water. As soon as it is cooled enough to handle, remove the wax from the water and pull like taffy until it becomes *light colored.* It may be applied with the fingers, if the hands have been carefully greased, or applied with a little stick while the wax is hot, if care be taken not to injure the parts waxed.

(*b*) Crown-grafting.—This method is generally used for shrubs, grape-vines, etc.

Directions: In crown-grafting the stock is prepared by cutting off the plant at the surface of the ground.

The process is the same as that of top-grafting, the only difference being the *position* of the graft.

**IV. Layering.**

This method of asexual reproduction differs from that of cutting, budding, and grafting, in that the new plant is rooted while still attached to the parent plant. This is not only the simplest, but also the most certain, method of bud propagation wherever practicable. In nature familiar examples of layering are the black raspberry (Fig. 55), strawberry, and dewberry. In fact, very many plants will send out roots if brought in contact with moist soil.

1. *Simple Layering.*—Directions for layering: (*a*) This is ordinarily done by merely bending down any one of the lower side shoots, placing it in a slight depression, pegging it down with a forked stick, and covering it with a few inches of mellow soil. In a dry season it will be necessary to moisten this soil, and mulch it with dry earth or grass.

(*b*) Under favorable conditions roots will form at the buried node, and a new plant may be secured by separating the rooted shoot from the old plant. If more than one plant is desired, bury as many nodes as the old plant will sustain.

2. *Mound Layering.*—A very simple process called mound layering is practiced where a number of new plants are desired from a single parent.

Directions for mound layering: (*a*) The parent plant is cut off at or near the surface of the ground before growth begins in the spring, and is called the "stool." By the following spring many shoots will have been produced.

(*b*) The stool and the base of the shoots are mounded up with soil to the depth of several inches. Roots will be formed at the underground nodes of these the same summer (Fig. 78).

(*c*) In autumn, or the following spring, the newly rooted shoots may be removed from the stool and transplanted as individual plants.

(*d*) The same stool may be repeatedly used, if well cared for by thorough cultivation and liberal applications of stable compost.

Any low, stubby plants—as, the gooseberry, or even the quince—may be advantageously propagated by mound layering.

Wherever the process of layering cannot be performed by bending the branch to meet the soil, the soil, or a substitute, may be lifted up to the branch. There are various devices used in doing this.

3. *Pot Layering.*—(1) The limb which has been par-

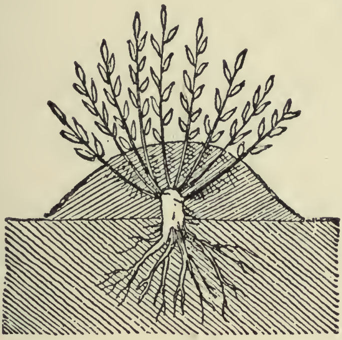


FIG. 78.—MOUND LAYERING.

tially girdled in order to check the backward flow of sap is surrounded by some moist material—as, sphagnum moss, vegetable fiber, or soil. This should be held in place by merely wrapping the moss or fiber closely about the wounded portion of the stem. This wrapping should form a ball about five or six inches in diameter, so that it will not dry out too quickly. This may be further protected by an additional covering of a heavy paper cone.

(2) Instead of the moss or fiber, layering pots containing soil may be used.

(*a*) A simple form of layering pot may be contrived from a tomato-can by cutting a hole in the bottom of the can slightly larger than the stem to be inclosed; then make a slit down one side of the

can and half-way across the bottom to the hole in the center.

(*b*) Carefully spring the can far enough apart to admit the limb (which should be well wrapped with cloth just where it is encircled by the bottom of the can, to keep it from being cut), and adjust it so that the girdled portion will be in about the center of the can.

(*c*) Wrap the can securely in both directions with wire, and support it by attaching the wire to an upper limb

(*d*) Now fill the can with moist soil, and see that it is kept moist.

(*e*) When the soil is filled with roots cut off the stem below the can, prune back the top, and transplant where desired.

An ingenious teacher may contrive many simple devices for layering by using such material as is at hand, as, chalk-boxes, etc.

(3) Where several layers are to be obtained at one time from a tall shrub of small tree, a long box of soil may be supported by a post beneath the twigs to be layered. These must be pegged down in the soil until rooted. For any particularly desirable bud variation ("sport") this plan is especially advantageous.

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# OUTLINE OF CHAPTER X.

## IMPROVEMENT OF PLANTS.

Basis of :

1. *Variation.*
2. *Heredity.*
3. *Selection.*

### *A.*—IMPROVEMENT OF EXISTING TYPES

**I. Selection of Seeds.**

1. *Table of Standards.*
2. *A Study in the Selection of Seeds.*

**II. Isolation of Seedlings.**

**III. Given Normal Conditions.**

**IV. Selection Should Be Repeated.**

**V. Example of Type Improvement.**

### *B.*—ORIGINATING NEW VARIETIES.

**I. Determining the Ideal.**

1. *Definite Characteristics.*
2. *Characteristics Chosen Along the Natural Development.*
3. *Characteristics Must Harmonize with Each Other.*
   (1) EARLINESS.
   (2) SIZE.
   (3) NUMBER.
4. *One Leading Characteristic.*

## II. Variation Furnishes the Starting-point.

1. *Variation of Seedlings.*
2. *Variation may be induced by—*
   - (1) Environmental Changes.
     - (*a*) Change in Food-supply.
     - (*b*) Light Relations.
     - (*c*) Pruning.
   - (2) Cross-fertilization.
     - (*a*) Limits of Crossing.
     - (*b*) Varying Results of Crossing
     - (*c*) Process of Cross-pollination.
3. *Bud Variation.*

## III. Fixing the Type.

### C.—REFERENCES.

# CHAPTER X.

## IMPROVEMENT OF PLANTS.

"*Those who improve plants are true benefactors.*"
—GOFF.

Variation, heredity, and selection form the basis of all plant improvement.

1. *Variation.*—It is evident that the first requisite toward the improvement of plants must be the power to vary; for were it not possible for plants to vary, no change could take place. It is these individual differences that make one plant more desirable than another, and that *furnish the starting-point for the improvement of the existing type, or for the origination of a new variety.*

2. *Heredity.*—While variation furnishes the starting-point, the desired characteristics would be of no avail in plant improvement were it not possible for them to be transmitted by heredity.

3. *Selection.*—By continued selection through a number of generations, the characteristics furnished by variation are preserved and accumulated through heredity.

### *A.*—IMPROVEMENT OF EXISTING TYPES.

When the object desired is simply to improve a given variety, individual plants can be found

in any field or garden crop which are especially good representatives of the existing type.

**I. Selection of Seeds.**

The very first thing to be done is to select the most perfectly developed seeds from those particular plants which most nearly conform to the standard of perfection for that type.


Agricultural Experiment Station, Ames, Iowa.

FIG. 79.—VARIATION IN GRAINS OF CORN.

No. 1 is best since the grains are full and plump at the tips next the cob, and have large germs indicating strong vitality and feeding value. Nos. 2, 11, and 12 are the next best forms in order. Nos. 5, 6, and 7 are weak, with low feeding value and small percentage of corn to cob. Since the grains are *not* uniform in size, the planter will not drop the same number in each hill. These grains were taken from ears that appeared to be good when examined from the standpoint of the ear, and shows the importance of paying more attention to the selection of grain from the seed ears of corn.

omit

EXERCISE 10.—*A Study in Selecting Seed for the Improvement of the Existing Type.*—If this subject is taken up in the fall, corn will afford excellent material for class work. It is probable that some members of the class will have access to a field of corn.

(*a*) Individual plants should be selected from various parts of the field—about twenty stalks in all. These plants should be neither abnormally large nor small.

## TABLE VI.

STANDARDS OF PERFECTION.*

| | NAME OF VARIETY. | | | | | |
|---|---|---|---|---|---|---|
| | *Reid's Yellow Dent.* | *Golden Eagle.* | *Riley's Favorite.* | *Leaming.* | *Boone County White.* | *Silver Mine.* |
| EAR— Shape | Slowly tapering. | Slowly tapering. | Slowly tapering. | Tapering. | Cylindrical. | Cylindrical. |
| Length | 10 in. | 9 in. | 9 in. | 10 in. | 10 in. | 9 in. |
| Circumference | 7 in. | 7 in. | 7 in. | 7 in. | 7.5 in. | 7 in. |
| ROWS— Number | 18–24 | 16–20 | 16–20 | 16–24 | 16–22 | 16–20 |
| Space | Narrow. | Medium. | Medium. | Medium. | Medium. | Narrow. |
| BUTT— Filling out | Deeply rounded, compressed. | Moderately rounded, compressed. | Moderately rounded, compressed, | Moderately rounded, compressed, expand'd | Moderately rounded, compressed. | Moderately rounded. |
| TIP— Filling out | Regular rows of kernels. | Regular rows of kernels. | Regular rows of kernels. | Irregular rows of kernels. | Regular rows of kernels. | Regular rows of kernels. |
| SHANK— Size | Small. | Small. | Small. | Medium. | Medium. | Medium. |
| KERNEL— Condition | Firm, upright. | Loose, upright. | Firm, upright. | Firm, upright. | Firm, upright. | Firm, upright. |
| Indentation | Medium, smooth. | Very rough. | Rough. | Rough. | Rough. | Very rough. |
| Color | Light yellow. | Deep yellow. | Deep yellow. | Deep yellow. | Pearl white. | Cream white. |
| Shape † | Long wedge. | Broad wedge. | Medium wedge. | Medium wedge. | Medium wedge. | Broad wedge. |
| PER CENT. CORN ‖ | 88 | 90 | 90 | 88 | 86 | 90 |
| COB— Size | Medium. | Small. | Small. | Medium. | Medium. | Small. |
| Color | Deep red. | Deep red. | Deep red. | Deep red. | White. | White. |

* Adapted from First Annual Report, Illinois Corn Growers' Association.

† Note shape of kernel *after* finding per cent. corn.

‖ To find per cent. of corn, weigh the ear, then shell the corn, taking care to keep the grains from the butt and tip separate from those of the remainder of the ear. Now weigh the cob, and subtract the weight from that of the ear to find weight of corn. Calculate the per cent. of corn to ear.

In their selection, the points to be considered are: size and regularity of stalk; strength of brace roots; development of leaves and tassels; number and development of ears, and their distance from the ground.

(*b*) Actual measurements and observations concerning these points should be made upon each plant selected, recorded on a tag, and securely fastened to the bag in which the ears of corn from that particular plant are enclosed.

(*c*) These bags of corn should now be taken to the classroom and the data upon the different tags compared—without removing the tags. *Those desirable points which most nearly coincide in the greatest number of plants* may be written upon a new tag.

(*d*) The original tags should now be compared with this new tag, and those bags containing the corn which grew upon the *plants most nearly conforming* to the new tag should be reserved for further study, and all others discarded.

(*e*) The ears of corn in each separate bag reserved may now be carefully examined, and actual observations and measurements made upon the points mentioned in the Table of Standards of Perfection.

(*f*) If the corn examined belongs to one of the varieties given in the table, the separate points obtained should be compared with the corresponding points of the standard for that variety.* Only those ears which most nearly coincide in the greatest number of points with the given standard of perfection should be selected for seed, and all others discarded.

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* If the variety studied is not one of those given in the Table, a standard of perfection should be determined upon by the class by comparing the data obtained from the various ears examined, and selecting for this standard the data containing the greatest number of desirable points.

(*g*) Only the grains obtained from the middle of these ears should be reserved for seed, discarding all imperfect ones (Fig. 79).*

## II. Isolation of Seedlings.

These seeds should be planted in a place where they will be isolated from other plants of the same or of a different variety with which they would readily mix, else they would be contaminated by their neighbors; for if they were not isolated from other individuals of the same variety, they would probably mix with inferior ones, and the improvement would, therefore, be less. For this reason, also, it would be well to weed out from the seedlings of the selected seeds all inferior plants before the pollen ripens.

If these selected seeds were planted near a different variety, the two varieties might mix,

* It may seem to some that undue importance is placed upon the details of this study. But comparatively few persons realize the bearing of careful, intelligent selection upon the improvement of the agricultural products of America. This is well illustrated in the results even of a few years in the improvement of corn by the Illinois corn growers through selection.

Bulletin 59, Missouri Agricultural Experiment Station, says: "To show this effect, we notice the average yield per acre of corn in the ten years between 1890 and 1900 was 22.8 per cent. greater than it was during the ten years between 1880 and 1890. In Missouri, for the same time, the increased yield per acre has been less than one per cent. (0.8 per cent.). The average value of corn per acre for the whole country during the last decade has decreased. But the value per acre in Illinois has decreased only 1 6 per cent., while the decrease in value of an acre in Missouri, where practically no attention has been given to corn breeding, has been 9.3 per cent."

See 3rd 5th

and the resulting offspring, in all probability, would not conform to the type.

**III. Given Normal Conditions.**

The seedlings should be kept *under normal conditions*, for any variation in the conditions would have a tendency to induce variation in the plant (see "Variation," p. 214).

**IV. Selection Should Be Repeated.**

From generation to generation, so that these type characteristics may be transmitted, accumulated, and fixed; thus will result the improvement of the type.

**V. Example of Type Improvement.**

As an example of the improvement of the existing type may be given the Boone County white corn improved by Mr. James Riley, of Indiana. He took for his type a fine white sort, selecting seed from the best-formed plants bearing two or three well-formed ears. He continued this selection for a number of years. In addition to this, he went through the fields just as the tassels were appearing and cut out all imperfect and barren stalks. In this way the type was improved, as is shown in Fig. 80.

### *B.*—ORIGINATING NEW VARIETIES.

**I. Determining the Ideal.**

1. The first step in originating a new variety is to *determine definitely the characteristics which one wishes to develop* in the new plant.

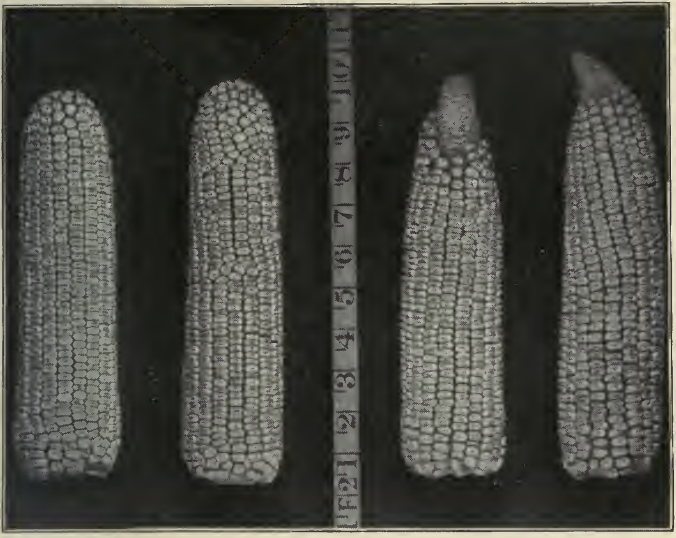

FIG. 80.—IMPROVEMENT OF CORN BY SELECTION.
Boone County white on left, and the original type from which it was developed by selection on right.

2. These desired characteristics must be *chosen along the line of the natural development of the plant.* In this way not only is the time lessened in reaching the desired variety, but the attainment of that variety is much more nearly certain.

3. *These characteristics must be in harmony with each other.*

(1) For example, if earliness is especially desired, size must not be expected, as in the earliest varieties—for example, sweet corn—the size not only of the ears but of the whole plant is much reduced.

(2) If size is desired, time and number must often be sacrificed. As Emerson says, "For everything you have missed, you have gained something else; and for everything you gain, you lose something." The Ponderosa tomato is a good example of increased size at the expense of number. A single plant bears about a dozen immense tomatoes.

(3) If number is to be increased, then size must necessarily be diminished. Of this the little preserving tomato affords a good example. A single plant sometimes yields several hundred tomatoes.

4. There should prevail *one leading characteristic.* Continued selection should be made with this predominating character in mind. If high flavor is the one character most desired, then all other characters must be made subordinate. In case other desirable qualities are found combined with high flavor in the same plant, as is often the case, it would then be advantageous to breed from that plant. For example, in breeding for high flavor in the strawberry, those plants should be chosen which possess the highest flavor, other characters being given secondary consideration; but if individual plants can be found which combine both qualities, prolificacy and flavor, it would, of course, be advisable to propagate from those particular plants.

**II. Variation Furnishes the Starting-point.**

1. *Variation of Seedlings.*—When the characteristics of the desired variety have been definitely determined, then if one will diligently and carefully search among his plants, he may find —owing to variation—individuals which possess these characters in a more marked degree than do the others. But if such individuals are not found, then

2. *Variation may be induced* by (1) ENVIRONMENTAL CHANGES.

Important among these is (*a*) a change in food-supply. Darwin says: "Of all the causes which induce variability, excess of food, whether or not changed in nature, is probably the most powerful."

If heavy foliage and rank-growing plants represent the "ideal," they should be given a liberal supply of nitrogeneous food (see "Effect of Nitrogen," Chapter IV.) If dwarf size and fruitfulness are the desired characters, then foods containing potash and phosphorus should be substituted.

EXPERIMENT 26.—(*a*) To show variation induced by change of food supply. Secure one-half bushel of pure white sand, and sterilize‡ it by thoroughly baking it in a hot oven. Omit

(*b*) The tomato, geranium, etc., are suitable plants for this experiment. Select three small, similarly developed plants grown from cuttings of the same stock (see page 220).

(*c*) Pot these plants in similar-sized small pots, re-potting as the sand in each pot becomes filled with roots. Place them under similar conditions as regards light, air, temperature, and water. Label the pots 1, 2, and 3.

(*d*) Prepare stock solution No. 1, containing the essential elements of plant-food in approximately the proper proportions, by thoroughly pulverizing and dissolving in 1,000 parts of water (say 1,000 *c. c.*) 15 parts monocalcium phosphate, 20 parts potassium sulphate, 2 parts magnesium sulphate, 30 parts sodium nitrate, and 2 parts sodium chloride—adding a few drops of some soluble iron compound.

Prepare stock solution No. 2 in every way like No. 1, except that you leave out the sodium nitrate.

Prepare stock solution No. 3 similar to No. 1, except that you leave out the potassium sulphate. (The mineral matter will not entirely dissolve, so these solutions should be well shaken before using.)

(*e*) When watering plant No. 1, occasionally add a definite amount of solution No. 1. (The condition of the plant must be the guide as to the time and amount of this food-supply.) Begin with a small amount, and gradually increase or diminish it.

At the same time add to the water used in watering plant No. 2 the same amount from stock solution No. 2, and to that used in watering plant No. 3 add the same amount of stock solution No. 3.

(*f*) Measurements and observations should be taken at stated times during several months upon the following points: Number, size, and color of leaves of each of these plants; hight and mean circumference of their stems; number and size of branches; time of flowering; number and character of blossoms; and in the tomato, the number, size, and quality of fruits.

Experiment 27.—If for any reason the above experiment is not practicable, substitute (*a*) ordinary soil (not


FIG. 81.—PLANT ROSETTES.

1—Pepper-grass. 2—Sow-thistle. 3—English Plantain. 4—Strawberry. 5—Common thistle. 6—Mullein. 7—Dandelion.

rich soil) for the sand; select the plants, and label the pots as in above experiment.

(*b*) When watering the plant in pot No. 2, add a small but definite amount of water leeched from wood ashes; when watering the one in pot No. 3, add the same amount of water leached from stable compost; when watering pot No. 1, add the same amount of each. As above, the condition of the plants must determine the time and amount of the food-supply.

(*c*) Make the same observations and comparisons as in Experiment 26 (*f*).

(*b*) Light is another factor in inducing variation among plants. Light, in some degree, is essential to the growth of all green plants. Hence, all such plants strive to adapt themselves with reference to their light relations—(*a*) in the arrangement of their leaves by the rosette habit (Fig. 81), as in the plantain and dandelion; (*b*) in the manner of branching and leaf-arrangement of trees; (*c*) in the elongation of and direction of the stems, as in the trees and vines of a dense forest; or (*d*) by turning toward the light, as in the sunflower.

O Experiment 28.—The student should be required to make actual observations and measurements of the variations of plants for adaptation to light from those plants of the same kind grown in the light and in the dark or partial darkness.

O Experiment 29.—Let him try to produce a voluble‡ stem by starting some erect plant—as, the potato or tomato—in a darkened place, so arranged that light is admitted only from one small opening (about three inches square) at one side and above the plant. When it

has made a growth of several inches, place a round, straight stick in the pot for its support, and bind it to it with a soft string, leaving about two inches of the top of the plant free. When this free portion has bent directly toward the light, gradually turn the pot so that as the tip again turns toward the light the stem will at the same time make a partial revolution around the support. (Fig 82).

Continue turning the pot in this manner throughout the growth of the plant. As the plant develops, it would be well to give it more light, but this should always be obtained from a northern exposure.

FIG. 82.—POTATO PLANT.

Voluble stem produced by Experiment 29.

(*c*) Variation Induced by Pruning (Fig. 83).—Not only is the food-supply distributed to a less number of branches, thereby increasing the amount to each branch, but the *form of the entire plant can be greatly modified by pruning.*

Buds or branches may be accidentally destroyed or intentionally removed. As an example of variation induced by accident may be given the origination of the Burpee Bush Lima bean.

In 1883 "Mr. Palmer's entire crop of large White Pole Limas was destroyed by cutworms."

He found one little plant which had been cut off about an inch above the ground, and had put out a new growth. "It bore three pods, each containing one seed."* These were planted the next spring, resulting in two dwarf plants. From these, by continued selection, the Burpee Bush Lima was developed.

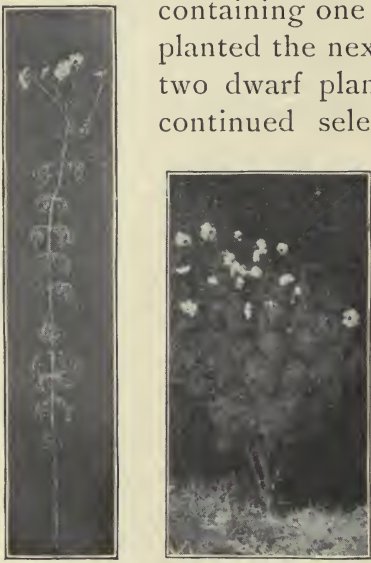

FIG. 83.—MODIFICATIONS OF COSMOS BY PRUNING.

Suggestion: If the school does not own a garden plot, the teacher should secure a vacant lot by paying a small rental, or, perhaps, by sharing the products. If this is not possible, then the work of pruning and cross-pollination must be done by those members of the class who can have access to private gardens, and their results reported to the class.

If it is desired to secure a stout, bushy plant, instead of a tall, single-stemmed one, let the student take the sunflower or Cosmos for example.

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* Bailey's *Plant-Breeding*, page 139.

EXPERIMENT 30.—(*a*) As soon as the terminal bud has become quite distinct, it should be removed.

(*b*) The development of lateral branches should be carefully watched and their terminal buds removed.

(*c*) This should be continued at will, according to the form of the plant desired (Fig. 83).

EXPERIMENT 31.—If size of blossom or of fruit is desired, all but a few of the flower buds should be removed, allowing those which are most advantageously situated in regard to light and food supply to remain.

The sunflower or Cosmos will afford good material for this experiment with reference to size of blossom, while the tomato will furnish excellent material with regard to size of fruit.

The modifications of the plant and the benefits to be derived from the various methods of pruning will be further discussed under the general subject of pruning.

(2) Variation may be induced by CROSS-FERTILIZATION. It may be possible that no plant can yet be found which combines the essential characteristics of the "ideal." In that case it would be advisable to select two plants, each of which possesses one or more of these characters, and to try to combine these in one plant by means of cross-fertilization.

The Trophy tomato well illustrates the combination in one plant of the desired characters of two separate plants. In 1850, Dr. Hand, of Baltimore County, Maryland, desired to unite the large size and firm flesh of the compound, much convoluted tomato with the smooth skin

of the small, juicy Love Apple. By cross-fertilization "he succeeded in putting the solid mass of this compound growth into the smooth skin of the Love Apple, and then, by careful selection and cultivation year after year, increased its size and solidity until it became a mass of flesh interspersed with small seed cells."

Another good example is that of the variegated hybrid carnation produced by crossing the pink variety (Scott) with the white McGowan (see colored plate).

(*a*) Limits of Crossing.—The two plants to be crossed must be members of the same family and of species, or varieties which are in some way closely allied. But even among these it is impossible to determine, without actual experiment, just what plants will cross with each other.

This uncertainty of crossing among plants is exemplified in the case of the pumpkin (*Cucurbita pepo*) and squash (*Cucurbita maxima*), which are species of the same genus, yet will not cross.* While with the strawberry and raspberry, which belong to different genera, a cross has been obtained.

(*b*) Varying Results of Crossing.—Even when a fertile cross is obtained, it may not show the desired characters in the first generation.† It

* *Year-book*, 1897, p. 389.

† "The first generation is constituted by plants grown from the seeds produced by the cross-pollinated flowers."—*Year-book*, 1897, p. 392.

should be borne in mind that "the possibilities are by no means exhausted, but it is quite possible that the descendants of these hybrids will yield valuable sorts."

In many cases the cross, or its descendants, may possess the desired characters of one parent, while those desired from the other parent may be entirely lacking. In that case "it would be advisable to cross the offspring with that parent * whose characteristics did not appear; for, by so doing the tendency to transmit those particular characters will be increased, for this tendency is itself variable."†

At the same time, the individual plants of the original cross should not be discarded for several generations, for there is in the offspring a slight atavistic‡ tendency, or a tendency to revert to the character of some remote ancestor; hence, at any time an individual plant may appear which presents the very characters desired.

In no instance can the plant-improver afford to neglect any condition or advantage which will tend to induce the desired variation.

(*c*) Process of Cross-pollination.—This consists in the transference of pollen from a flower of one plant selected to be crossed to the stigma of a flower from the other plant selected. In

* *Year-book*, 1899, p. 484.

† *Year-book*, 1898, pp. 355–357.

order to do this, it is simply necessary to understand the nature and arrangement of the parts of a flower (Fig. 84).

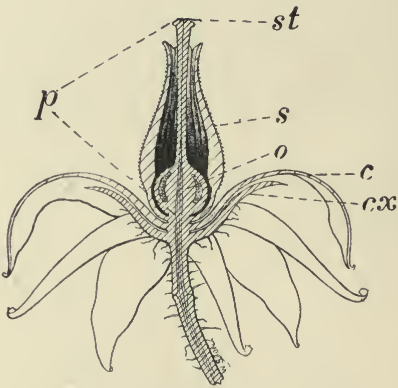


FIG. 84.—THE PARTS OF A FLOWER.

*Parts of a Flower.*—A typical flower consists of four kinds of organs (calyx, corolla, stamens, and pistil), the parts of which vary in form and number in the flowers of different species.

Starting from the outside, the first whorl is the calyx (*cx*), the separate parts of which are the sepals, usually green. The whorl just within the calyx is the corolla (*c*), composed of petals, which are often bright colored.

Within the corolla are the stamens (*s*), consisting of filament, or stalk, and anther, or pollen-sac. In the center of the flower is the pistil (*p*), a stalk-like organ, the upper portion of which is somewhat rough and swollen, and is known as the stigma (*st*). The stamens and pistil are the only organs concerned in reproduction, the others being merely accessory.

The organs concerned in fertilization are the stamens (male organs) and the pistils (female organs). In many plants both stamens and pistils are borne on the same flower—as, the bean and pea; in others they are borne on the same

plant but in separate flowers—as, the corn and cucumber; while in still others they are produced on separate plants—as, the ash and box elder.

In case both stamens and pistils are borne on the same flower, the anthers must be removed

a b c

FIG. 85.—ORANGE BUD AND BLOSSOMS.

*a*—Orange bud. *b*—Mature orange blossom. *c*—An emasculated flower.

before the pollen is shed, to prevent self-fertilization. To be sure of this, they should be removed before the bud is fully opened (Fig. 85, *a*), and in certain cases—as, wheat, etc.—in even an earlier stage, since pollination takes place before the bud opens.

Directions for cross-pollination: (*a*) The bud should be carefully opened to expose the anthers (Fig. 85, *b*), which should be picked off (Fig. 85, *c*) with a pair of tweezers, or cut off with a pair of tiny scissors. The best results will be obtained by selecting two or three of the strongest flowers of the cluster for emasculation, and removing all others.

(*b*) The flower cluster thus treated should be at once enclosed in a paper bag, the open end of which should have been slightly moistened by quickly dipping it in

water. Now the bag should be carefully tied around the twig, below the flower cluster, so as to insure the exclusion of insects and undesirable pollen (Fig 86*a*).

(*c*) The bag should be removed from time to time and the stigma examined with a hand-lens, to see if it is ready to receive the pollen. This can usually be told


FIG. 86*a*.
ORANGE FLOWER
Enclosed in paper bag after emasculation.

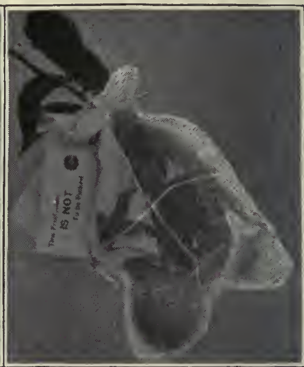

FIG. 86*b*.—NEARLY MATURE HYBRID ORANGE
Enclosed in gauze bag to prevent loss by dropping.

by the presence of a mucilaginous excretion, or by the appearance of papillæ upon the surface of the stigma.

(*d*) It should not be forgotten that the flowers from the other plant selected to be crossed must likewise be protected from insects and foreign pollen. This is done by enclosing the entire flower cluster in a paper bag before the bud opens.

(*e*) When the anthers begin to open, the pollen should be collected, labeled, and kept until the stigma is ready to be fertilized. Then the pollen is gently applied to the stigma by means of a fine-pointed scalpel or even a penknife.

(*f*) When the stigma is pollinated, it should be resacked and labeled.

(*g*) After the fruit is set, it might be well to replace the paper sack with a gauze one (Fig. 86*b*), which should be allowed to remain until the fruit is ripe, thus freely admitting air and light, yet affording protection from insects and birds, and preventing its loss by falling or being picked through mistake.

3. *Bud Variation.*—It may be that a single branch may show new and striking characters (Fig. 87), and possibly very desirable ones; for example, the smooth skin of the nectarine is the product of a bud variation of the peach, and the mossy stem of the moss-rose is also a bud variation or so-called sport.*

It becomes necessary to perpetuate such variations by bud propagation, since the characters of the plant as a whole are more likely to be reproduced through the seed, even of that particular branch, than are the characters of a single branch.†

### III. Fixing the Type.

It must be remembered that thus far *only a starting-point* for a variety has been obtained. It yet remains "to fix" that variety—that is, to make it "come true" from seed. This requires far more skill and patience than the work of securing the desired variation in the first place.

"Selection is the force which augments, de-

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* Bailey's *Plant Breeding*, p. 161. † *Year-book*, 1898, 357.

FIG. 87.—COSMOS FLOWERS.
From same stem, showing variation.

velops, and fixes type."* When a seedling possesses desirable qualities, "it is almost invariably necessary to render these characters hereditary by careful and continued selection and in-and-inbreeding through several generations."

* *Year-book*, 1897, p. 408.

While the tendency of the plant to vary is so essential in furnishing the starting-point for a new variety, it is also the most *difficult factor to overcome* in making that variety approach a fixed type; for out of a number of seeds from the plant having the desired characters, only one

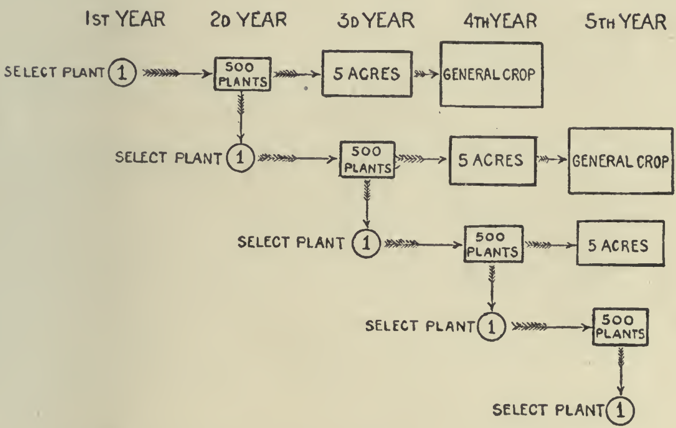


FIG. 88.—DIAGRAM SHOWING METHOD OF SELECTING AND IMPROVING SEED.

may come true. In that case, seeds should be used from that one plant only, and these planted in an isolated place. Possibly the next generation may furnish several of the desired plants, and again seed must be selected only from these.

*With selection, isolation, and cultivation continued* for many generations, one may hope to obtain seeds the majority of which will come

true. But the work of *selecting* the best seeds from the most uniform and typical plants must never be neglected, or the plants will in time revert to degenerate types.

If inbreeding is not possible, the variety may be perpetuated by bud propagation where practicable; indeed, in many cases it is the possibility of propagating by buds that makes the crossing of plants profitable.*

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* Bailey's *Plant Breeding*, p. 51.

# OUTLINE OF CHAPTER XI.

## PRUNING OF PLANTS.

### General Principles.

1. *Development of the Organism.*
2. *Purpose of the Plant to Itself.*
3. *Mutual Relation Between Root and Top.*

## *A.*—HOW TO PRUNE.

### I. Nature of the Wound.

1. *Function of the Cambium.*
2. *Effect of Improper Pruning.*

### II. Removal of Large Limbs.

### III. Treatment of Wounds.

1. *Pine Tar.*
2. *Grafting-wax.*
3. *Lead Paint.*

### IV. Pruning Back of Small Limbs.

1. *Removal of Buds.*
2. *Removal of New Growth.*

## *B.*—WHEN TO PRUNE.

### I. Fall Pruning.

1. *Advantages:*
   (1) CONSERVES FOOD.
   (2) PREVENTS DISEASE.
2. *Disadvantage:*
   NOT CONDUCIVE TO HEALING.

**II. Spring Pruning.**

1. *Advantage:*

CONDUCIVE TO HEALING.

2. *Disadvantage:*

WASTE OF FOOD.

**III. Summer Pruning.**

(See *A.*—IV., 1.)

## *C.*—WHY TO PRUNE.

**I. Pruning at Transplanting.**

1. *Trees for Fruit.*
2. *Trees for Timber.*
3. *Trees for Shade.*

**II. Pruning to Induce Fruitfulness.**

**III. Pruning to Prevent Overbearing.**

**IV. Pruning Hardy Shrubs.**

## *D.*—REFERENCES.

# CHAPTER XI.

## PRUNING OF PLANTS.

### I. General Principles.

Sound reasoning is the first requisite to success in pruning.

1. It should be borne in mind that the first work of importance in growing a plant is the *development of a strong, well-formed organism.* This development depends upon selection, pruning, food supply, and other environmental conditions.

2. The basic principle of all subsequent pruning is the fact that the paramount *purpose of the plant* (*to itself*) is that of perpetuating the species, and that it does this both asexually and sexually.

Asexual reproduction is accomplished by the formation of buds, which develop into branches. These may or may not become separate plants.

Sexual reproduction is accomplished by the formation of buds, which develop into flowers and fruit, the seed of which give rise to separate plants. One of these methods of reproduction is apt to predominate, and hence the food supply will be taken for its support at the expense of the other method.

Pruning is an important factor in regulating and, in a measure, controlling these two adverse tendencies of the plant to suit man's purposes.

3. Another point which must not be overlooked is the *mutual relation between root and top.* In the normally developed plant there is a state of equilibrium between the leaf-system and the root-system. As the top develops there must be a corresponding development of roots to supply the crude material to be converted into food by the leaves, and in turn there must be a corresponding growth of the leaf-system—if the root-system is to be enlarged—in order to convert the crude material into food for the growth of new roots. Hence, when this equilibrium is disturbed, either accidentally or on purpose, the plant bends its energies to restore it. Thus it is that pruning the roots checks the growth of top, and pruning the top not only checks the growth of roots, but gives increased food supply to the remaining parts.

## *A.*—HOW TO PRUNE.

### I. Nature of the Wound.

It will be seen from a careful study of a cross-section of a stem (Fig. 89), that in order for the cut surface to heal it must be in *direct communication with the cambium layer of the supporting stem.*

1. *Function of the Cambium.*—The process

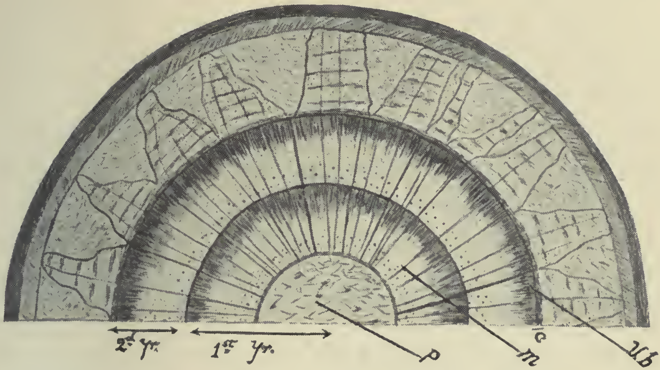


FIG. 89.—DIAGRAMMATIC CROSS-SECTION OF A BASSWOOD STEM TWO YEARS OLD.

*p*—Pith. *m*—Medullary rays. *c*—Cambium. *vb*—Vascular bundle.

of healing is carried on by the throwing out of new tissue at the cut edge of the cambium, which gradually rolls out from the circumference toward the center of the wound (Fig. 90), where in time it unites and forms a continuous layer of cambium, which gives rise to both wood and bark cells, as in any other portion of the stem.

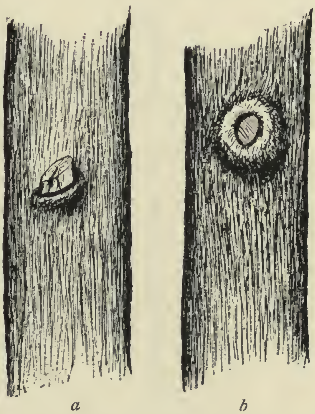


FIG. 90.—IMPROPER AND PROPER PRUNING.

*a*—Cannot heal. *b*—Healing.

*It is of the utmost importance* that in removing the limb the cut should be made in such a manner as to bring all parts of its circumfer-

ence as near as possible to the supporting stem. This is done by making the cut surface parallel to it (Fig. 90) ; for in this case the cut edge of the cambium still receives its food supply from the supporting stem.

2. *Effect of Improper Pruning.*—But if the limb is cut off so as to leave a projecting stub, healing cannot take place, since the prepared food for the support of this branch was elaborated by its leaves and *sent toward the trunk;* the supply having been removed, the cambium layer of this stub cannot grow. As a result, not only will the healing be prevented, but the cambium and bark will die back, leaving an unsightly stub of wood to rot down to the supporting limb or trunk ; and when the stub drops out, dust, water, and fungi, or other vegetation, will collect in the cavity left (Fig. 91), and thus introduce disease and decay into the heart of the tree, weakening its structure and possibly destroying it.

**II. Removal of Large Limbs.**

Should it become necessary to remove a large limb, it would be advisable to saw it off about a foot from the trunk of the tree, so there would be less danger of splitting down the trunk by the weight of the limb. This danger would be further lessened by making two cuts—the first below the limb to about the center, the second cut above the limb and just beyond the first cut,

FIG. 91.—GRASS GROWING IN CAVITY—RESULT OF IMPROPER PRUNING.

FIG. 92.—SAME TREE AS IN FIG. 91 AFTER CAVITY HAS BEEN REPAIRED. (*Reduced.*)

Treatment of cavity: The water was first drawn off by a siphon and the decayed wood cut out. It was then washed with a solution of formalin and left exposed to the air for a few days; then dried thoroughly, filled with pieces of rock, and cemented over with asphalt.

as in Fig. 93. The remaining stub should now be sawed off close to the trunk (see Fig. 90, *b*).

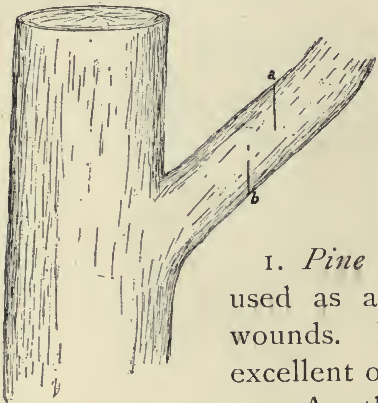


FIG. 93.—THE WAY TO REMOVE A LARGE LIMB.

**III. Treatment of Wounds.**

Where the cut surface is large, some protective substance should be applied to the exposed tissue.

1. *Pine Tar* is sometimes used as a dressing for these wounds. It is regarded as an excellent one.

2. Another dressing which may be used upon any tree without injury is *Grafting-wax* (see Chapter IX., p. 237).

3. *Lead Paint* is doubtless the best dressing for all kinds of trees, since it is not only durable, but to some extent *antiseptic*, and comparatively inexpensive.

**IV. Pruning Back of Small Limbs.**

1. *Removal of Buds.*—The ideal method of pruning, or that which would insure to the plant the least waste of energy, is the pinching or rubbing off of buds that would develop into branches which would need to be pruned off.

This method of pruning is especially adapted to the early or formative period of a plant's development. If close attention be given to the

removal of buds the plant may be made to conform to any desired shape.

By the removal of the terminal bud the plant may be made to put out lateral branches, and thus become short and bushy (Fig. 83), or by removing the lateral branches it will throw the more vigor into the central stem, causing it to become long and slender.

2. *Removal of New Growth.*—In large trees the above method is impracticable. The best practical method for such trees is to inspect them each year and remove such branches, or portions of branches, as growth may indicate.

FIG. 94.—WHERE TO CUT THE NEW GROWTH.

In doing this pruning the branch should be cut off just above a bud (as in Fig. 94), taking care not to cut too close to the bud, as it would then dry out.

## *B.*—WHEN TO PRUNE.

If the purpose of pruning is merely to remove dead or deceased branches, or the pinching off of superflous or undesirable buds, the work may be done at any time when it is necessary.

It is agreed by the best authorities that general pruning should be done while the trees are in a dormant state. There is, however, a dif-

ference of opinion among these authorities as to whether this work should be done as soon as the leaves are shed in the fall or before the buds have begun to swell in the spring.

**I. Fall Pruning.**

1. *The advantages* of fall pruning are: (1) that a greater amount of food would then be distributed over a less number of branches; for by spring, owing to the slow dissemination of food taking place through the winter months, the nutriment would already have been distributed to all the branches of the tree, particularly to their terminal portions, which would be removed by spring pruning;* (2) that immature branches, which would probably be frozen and tend to injure the tree, would thus be removed.

2. However, there is one *decided disadvantage* in fall pruning; that is, that the wound does not readily heal. This is due to the fact that healing is affected by the growth of the cambium layer, and as this is inactive in winter, healing cannot take place at that time. Hence, the exposed surface is liable to dry out or freeze, thereby inducing decay of the wood and inviting disease.

**II. Spring Pruning.**

1. The main *advantage* of spring pruning lies in the fact that the wound readily heals, owing to the *active* condition of the cambium layer.

* Authorities are not agreed upon this point.

2. The chief *disadvantage* is the waste of energy of the plant in the loss of the accumulated food supply by the removal of the terminal portions of the branches.

Exercise 11.—To study the effect of fall and spring pruning, let the student remove several small branches of as many different kinds of trees as are accessible, carefully labeling each branch pruned with the student's name and the date of pruning.

In the spring let them prune off as many more branches from the same trees and label with date.

Just before school closes for the year critically examine *all* the branches pruned. Compare and tabulate results. Was the result in each case due to the time of pruning or to the position and nature of the cut?

## *C.*—WHY TO PRUNE.

One should never remove a limb or even a twig from a tree without knowing why.

### I. Pruning at Transplanting.

The utmost care should be taken in lifting plants for transplanting, but even then many of the fine feeding roots will be broken off or mutilated; consequently, the equilibrium between root and leaf will have been destroyed.

To re-establish the equilibrium: first, all the mutilated roots should be cut off, so that the energy of the plant may not be wasted in trying to restore these injured parts; second, the leaf-bearing surface should be reduced to correspond to the loss of root-system. This principle holds good in the transplanting of any plant.

The *manner* in which plants are pruned at transplanting depends largely upon the purpose

Photographed by J. Craig, U. S. Dept. Agr.

FIG. 95.—APPLE-TREE HEADED LOW.

for which the tree is grown. If grown for *fruit* the tree should be headed low (Fig. 95); that is, the first limbs branching out from the trunk

U. S. Dept. Agr.

FIG. 96.—TREES GROWN CLOSE TOGETHER FOR TIMBER.

should not be more than eighteen inches from the ground. At the same time the lateral branches should be pruned back so that the central stem will lead.

The advantages of heading a tree low are: (1) it makes a tree stronger and less liable to be

blown over; (2) the trunk is thus protected from the direct rays of the sun, thereby preventing sun-scald; (3) that the tree's energy is conserved by lessening the distance through which the food is carried; (4) that the fruit is easier gathered.

The greatest objection in heading a tree low is that it renders cultivation more difficult.

2. If a tree is grown for *timber*, a tall, straight trunk should be encouraged by pruning off most of the lateral branches and planting the trees close together (Fig. 96), so that they will be forced to grow upright to obtain the light. As the trees develop, and room and food supply become insufficient, some of them should be removed.

3. Slow-growing *shade-trees* require very little or no pruning, save the removal of diseased or broken branches. But rapid-growing shade-trees—as, some of the maples—should have a portion of the last season's growth pruned back each year, thus forming a compact head, making the tree stronger, and obviating the necessity of severe top-pruning, which renders the tree useless (for shade, at least) for one year, as well as presenting a very unsightly appearance.

**II. Pruning to Induce Fruitfulness.**

As has been said, the paramount natural purpose of a plant is that of reproduction. Every plant has a certain amount of available food. In

FIG. 97.—NORWAY MAPLE
(*Acer platanoides*).
Horticultural Grounds, Missouri Experiment Station.

the early years of its development this food supply should be directed to the upbuilding of a strong, vigorous tree; but when the tree is mature, if one system of reproduction predominates over the other, it uses more than its share of this available food and the other system is deprived of its rightful portion, and thus its development is checked.

Man may, by pruning or other means, equalize the distribution of food. If vegetative

growth or asexual reproduction is so far in the ascendency as to prevent the development of fruit, this growth should be checked. Slight "heading-in induces fruitfulness by checking growth and by encouraging the formation of side spurs upon which fruit may be borne." *

In extreme cases, where a tree has never fruited, the growth may be checked by reducing the food supply. This may be done by withholding fertilizers, or stopping cultivation and seeding down in grass or clover for a few years, or by judicious root pruning.

*Root Pruning.*—Root pruning is attended by considerable risk, as the equilibrum between root-system and leaf-system is thus destroyed.

There is less danger of injury to the tree when the work is done in spring, as evaporation is less, and the conditions at this season of the year are more favorable for the readjustment of the growth.

Roots are sometimes pruned in summer, when the wood and fruit buds are developing for the next year; thus the formation of fruit buds would be encouraged. But at this period of the year the process is attended by a greater risk, as evaporation is very great.

The work is done by making a circular ditch around the tree at a distance from the trunk corresponding to the tips of the branches. One

* Bailey's *Principles of Agriculture*, p. 166.

should be *extremely cautious* as to the extent of the root surface removed, since the small, growing roots are the feeding roots upon which the plant is dependent for nourishment.

**III. Pruning to Prevent Overbearing.**

If sexual reproduction or the development of fruit predominates to such an extent as to be detrimental to vegetative growth, it should be checked by the removal of fruit buds, or a portion of the fruit, or even of some of the fruit-bearing branches. At the same time the vegetative growth should be encouraged by increasing the food supply through renewed cultivation and the application of nitrogenous fertilizers.

**IV. Pruning Hardy Shrubs.**

If the shrubs are grown for a hedge—as, the barberry (*Berberis vulgaris*), burning-bush (*Pyrus Japonica*), or osage orange—the new growth should be sheared each year, forming a compact head; but if the shrubs are grown for flowers and their natural beauty—as, the spiræas and roses—the young stems should not be pruned back, because they produce the flowers for the next year.

To admit more freely the air and light, the old branches—and, if too thick, some of the entire flowering stems—should be cut out. This will tend to increase the size of the blossoms, which may be further enlarged by pinching out

some of the flower buds. (See "Plant Improvement.")

EXERCISE 12.—In completing this study of pruning, an expedition should be made to an orchard or grove, for the purpose of observing the actual conditions of all phases of the work suggested in this chapter.

A written report should be required, touching upon all the points of the outline, which are exemplified by any plants seen during the trip. (*a*) Note upon a mature plant the effect, upon its use and upon its strength, produced by correct, incorrect, or no pruning in its early stages of development.

(*b*) If in fruiting season, do you note any trees which are overbearing? Any that are not bearing? Can you see why? How would you effect a change?

(*c*) Examine a limb several years old. Compare the growth made in one year with that of each successive year. How do you account for the existing conditions? Take a limb of the same age from a neighboring tree, but of a different kind. How does a year's growth in one tree compare with that of the same year of the other? How do you account for this?

(*d*) Note wounds that are healing. Describe and explain. Do you note any that have not healed? Why? Could this condition have been prevented? Explain. How will it affect the tree? What treatment would you advise?

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# OUTLINE OF CHAPTER XII.

## ENEMIES OF PLANTS.

### *A.*—INJURIOUS INSECTS.

**I. General Characters of Insects.**

**II. Metamorphosis.**

**III. Apparatus Needed in Collecting and Rearing Insects.**

1. *Net.*
2. *Cyanide Bottle.*
3. *Breeding-jars.*

**IV. Field Trip.**

**V. Laboratory Studies.**

1. *Study of the Live Insect.*
2. *Grasshopper.*
3. *Nymph.*
4. *Butterfly, or Moth.*
5. *Caterpillar.*

**VI. Economic Classification of Insects.**

1. *Group I.—With Biting Mouth-parts.*
2. *Group II.—With Sucking Mouth-parts.*

**VII. Preventives.**

1. *Removal of Débris.*
2. *Change of Crops.*

**VIII. Insecticides.**

1. *Group I.—Poisonous Insecticides.*
2. *Group II.—Contact Insecticides.*

**IX. Study on Spraying.**

**X. Natural Enemies.**

1. *The Birds.*
2. *Predaceous Insects.*
    (1) SPECIFIC EXAMPLES.
    (2) REQUIRED EXERCISE.

**XI. Specific Examples of Injurious Insects.**

1. *Plant-lice.*
2. *Rose-slug.*
3. *Tent-caterpillar.*
4. *Forest Tent-caterpillar.*
5. *Codling-moth.*
6. *The Borers.*
    (1) EXAMPLE: THE ROUND-HEADED APPLE-TREE BORER.
    (2) PREVENTIVES.

## *B.*—INJURIOUS FUNGI.

**I. Specific Examples.**

1. *Brown Rot.*
2. *Black Rot.*
3. *Bitter Rot.*
4. *Apple Scab.*

**II. Fungicides.**

1. *Bordeaux Mixture. Dust Bordeaux.*
2. *Ammoniacal Copper Carbonate.*

## *C.*—REFERENCES.

# CHAPTER XII.

## ENEMIES OF PLANTS.

In dealing with plants one of the most important problems which arises is how to meet their enemies. In order to do this one must know something of the nature and habits of each particular species which he needs to control. Actual observation of them at work is the best means of obtaining a knowledge of the enemies of plants. But some good work on insects and fungi (like those listed at the end of the chapter) should be consulted, or if none of these are at hand, one should write to one's own State Entomologist for advice and literature.

These enemies may be divided into two great classes: (1) animal forms, (2) plant forms. Among animal forms the most important enemies of plants are *injurious* insects.

### *A.*—INJURIOUS INSECTS.

**I. The General Characters of Insects**

in the adult state are one pair of antennæ; three body divisions, head, thorax, and abdomen; three pairs of legs, and two pairs of wings.

**II. Metamorphosis, or Development, of Insects.**

All insects develop from eggs, and all undergo a more or less marked change in form during their life-cycle.*

Many insects when they emerge from the egg are much like the adult form. These *nymphs*, as they are called, have no wings. They feed greedily, and as growth demands the hardened skins split and are cast—that is, the insects molt. The wings, if wings are present in the adult stage, develop as little pads, which grow larger with each molt until the adult stage is reached, when growth ceases. This method of development is called *incomplete metamorphosis*, the three stages of which are egg, nymph, and adult. Common examples of this method of development are grasshoppers, crickets, plant-lice, and dragon-flies.

Many other insects, when they leave the egg, differ markedly in form from that of the adult. These caterpillars, grubs, maggots, etc., as the case may be, are called the larvæ. In this larval or second stage they feed, grow, and molt, but do not change their form. When they are full grown they stop eating, become restless, and pass into the third stage of their development (that of the pupa), some attaching themselves to a stick or leaf, others spinning a cocoon, while

* Those insects belonging to the small order *Thysanura* undergo no metamorphosis.

still others form a leathery case and bury themselves in the ground. Here they remain quiet for a time, when the pupa-cases split open and the adult forms emerge, lay their eggs, and thus

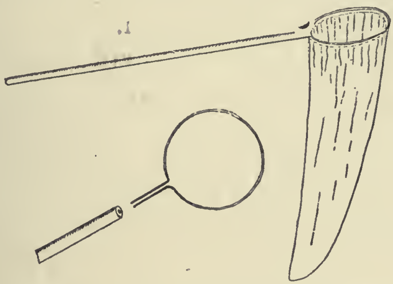


FIG. 98.—NET FOR COLLECTING INSECTS.

their life-cycle is completed, and the life-cycle of another generation is begun.

**III. Apparatus Needed in Collecting and Rearing Insects.**

A few simple, inexpensive articles are all that is necessary. Nets, cyanide bottles (Fig. 99), and a few empty bottles will be needed in collecting.

1. *The net* may be made by bending a heavy wire into a circle about a foot in diameter, turning the ends of the wire out, as shown in Fig. 98. For a handle an old broomstick may be used. A hole should be made in the end by burning it with a hot iron rod or boring it with a small bit. Now fasten the ends of the wire firmly into this hole with pegs or nails. Make a cheese-cloth sack a yard long, round one cor-

ner off, and firmly sew the open end to the wire, as in Fig. 98.

2. *Cyanide Bottle for Killing Insects.*—Place in a wide-mouthed bottle, which will hold about a pint, a few small pieces of potassium cyanide. This should be handled with great care, as it is

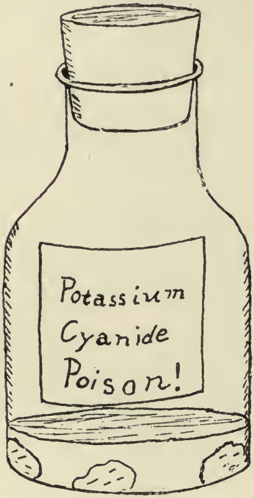



FIG. 99.—CYANIDE BOTTLE.

FIG. 100.—BREEDING-JAR FOR REARING INSECTS.

*extremely poisonous.* Now cover the cyanide with a layer of plaster of Paris. Thoroughly moisten the plaster of Paris with water, pouring it in slowly through a funnel to prevent the sides of the bottle from being smeared. Let it stand until the plaster of Paris sets. Remove any surplus water, and allow the bottle to become thoroughly dry before using. Tightly

close the bottle with a cork thick enough to be easily removed (Fig. 99).

3. *Breeding-jars* for rearing insects should be prepared before the insects are collected. Place about two inches of clean sand in the bottom of glass fruit-jars; moisten the sand, and provide covers of cheese-cloth, or mosquito-netting, and narrow rubber bands to keep them in place.

### IV. Field Trip.

Equipped with net, cyanide bottle, and empty bottles for the reception of live insects, the class should make a field trip to study the habitat and the habits of insects, and to collect their own material for laboratory work.

(*a*) Look in the grass and weeds, under leaves, stones and boards, and on the bark of trees. Are some insects harder to find than others? Why? Why do you find certain kinds in one place rather than in another? Observe especially upon what plants and what part of the plant each species is found feeding. Collect a portion of this plant to place in the breeding-jar with this insect when you get home. Notice how the plant has been affected by the feeding of the insect. Are there any holes in the leaves or stem? How were they made? In what stage of the development of the insect was the damage done? (See "Water Forms," *a* and *b*.)

### V. Laboratory Studies.

1. *Study of the Live Insect.*—Keep each species of insect in the breeding-jars supplied with fresh food, and watch each through all the subsequent changes of development.

(*a*) Make careful notes and drawings on each stage.

(*b*) Does the insect eat the tissue or simply suck the juices of its plant-food? *How* does it obtain its food in each stage of development?

(*c*) Will any of the insects in the larval or adult form eat other insects in any stage of development?

WATER FORMS.—If the students have access to a pond or stream, it would be both interesting and instructive

FIG. 101.—COLLECTING INSECTS.

to (*a*) collect forms which pass through some or all the stages of development in the water.

(*b*) Take a quantity of the mud and water in which these water forms are found, together with algæ, or other food, back to the laboratory, and place with the different species in breeding-jars similar to that in Fig. 100.

(*c*) Observe all changes in their development, and make careful notes and drawings of each stage.

(*d*) If there are a number of any one kind, it would

be well to preserve some of them in a solution of formalin (made by mixing one part of formaldehyde, 40 per cent., with 19 parts of water) for museum specimens. If possible, have each stage of every species represented in your collection of specimens.

2. *The Grasshopper.*—Find the three body divisions—head, thorax, and abdomen.

THE HEAD.—(1) Find the *antennæ* (slender feelers). How many segments in each? Draw.

(2) Find the *compound eyes.* Examine a portion of one under the low power of the microscope. What is the general shape of these parts, or *facets*, of the eye? Draw several of them. In what direction can the grasshopper see?

(3) How many *ocelli*, or simple eyes, do you find?

(4) MOUTH-PARTS.—(*a*) Find the *labrum*, or upper lip. Lift and remove it. Draw.

(*b*) Note the *mandibles*, or true jaws, exposed by the removal of the *labrum.* In what direction can you move them? Take out one. Draw. Does the grasshopper obtain its food by biting or sucking?

(*c*) Find the *labium*, or lower lip. Remove it. Draw. Is it a single appendage or two united?

(*d*) Look for the *labial palpi* attached to the *labium.* How many segments in each *palpus?*

(*e*) Find the *maxillæ*, just in front of the *labium.* These each consist of three parts united at the base; the outer one, the *maxillary pulpus;* the middle one, a spoon-shaped piece, the *galea;* the inner piece, the *lacinia*, (*maxilla* proper). Draw.

(5) Take a fresh specimen and draw a front view of the head, labeling all the parts.*

* Every question in the above outline should be answered by actual observations upon the insects. It may be that the student will be better able to answer some of these questions, *after* having made the laboratory study of the live insect.

The Thorax.—The segments of the thorax are the *prothorax*, *mesothorax*, and *metathorax*. (1) What appendages has each? Look on the mesothorax, just above the legs, for a pair of spiracles or breathing pores. Do you find another pair between mesothorax and metathorax? (2) Draw the thorax, and label the parts.

The Legs.—(1) How do the first and second pair of legs differ from the third pair in size, and in the direction in which they extend from the body? Why? What modes of locomotion has the grasshopper?

(2) Make a careful study of the hind legs. (*a*) Note *the coxa*, a short segment attached to the body. Next to it is the *trochanter*, another short segment. The *femur* is the large segment following this, attached to which is the slender *tibia*. With what is the latter armed? For what purpose? The terminal portion is the *tarsus* or foot. Is it segmented? Note the hooks and pads.

(*b*) Make a drawing of the entire leg, and label each part.

The Wings.—(*a*) Note the wings on one side of the body while folded, and their position with reference to the body; with reference to each other.

(*b*) Spread them out and compare as to size, shape, color, use, texture, and position.

(*c*) Make a careful drawing.

The Abdomen.—(1) How many abdominal segments do you find? Are the last three distinct?

(2) (*a*) Look along the groove on each side of the abdomen for spiracles. How many in each of these segments? In how many segments are they found?

(*b*) Catch a live grasshopper and watch it breathe. Do the walls of the abdomen move? What movements have the spiracles? Try to drown the grasshopper by holding its head under water. Explain.

(3) Find the ear membrane on the side of the first segment.

(4) (*a*) Examine the end of the abdomen. Is it blunt, and do you find two appendages, the *cerci*, on the upper side? If so, the specimen is a male. If the end of the abdomen is tapering and divided into four points—parts of the ovipositor—the specimen is a female.

(*b*) Draw the abdomen, showing all the parts.

Draw the entire grasshopper as seen from the side. Now, before discarding the specimen, cut through the mouth beyond the œsophagus into the crop, open it, and examine its contents. See if you can find out what is the grasshopper's food.

3. *The Nymph, or Young Grasshopper.*—Do you find all the parts mentioned in the study of the adult grasshopper present in your specimen? (*a*) Compare the parts with those of the adult.

(*b*) Draw a side view of the nymph.

4. *The Butterfly, or Moth.*—Identify the three body divisions, and locate the antennæ, eyes, legs, wings, and spiracles. Compare with those of the grasshopper.

MOUTH-PARTS.—Make a careful study of the mouth-parts. (1) Note the two short projections, the *labial palpi*, in the front of the head.

(2) Uncoil the long tube between the *palpi* and examine it. The parts of the tube correspond to the maxillæ of the grasshopper.

(3) (*a*) Does the butterfly obtain its food by sucking or biting? Are there other mouth-parts present?

(*b*) Make a drawing of the mouth-parts present in their natural position.

(*c*) Remove them, and draw.

5. *Caterpillar.*—Make a careful examination of some caterpillar, the larva of a moth or butterfly—for example, the tomato-worm.

(1) Do you find the general characters of the adult insect—three body divisions, one pair of antennæ, and three pairs of legs—in the caterpillar?

(2) Do you find eyes, spiracles, and mouth-parts? How do they compare with those of the adult moth? (See mouth-parts of the butterfly.)

(3) Make drawings of the entire larva, showing all parts.

(4) Remove the mouth-parts, and draw. Are they adapted for biting or sucking?

### VI. Economic Classification of Insects.

Insects are divided into two great groups according to their mouth-parts, in order that one may know what insecticides to apply in combating them

*Group I.*—This includes all insects in that stage of their development in which their mouth parts are formed for biting. These insects actually bite off, chew, and swallow small portions of the plant or other material upon which they feed. Consequently, they would be killed by poison placed upon the food and taken into the stomach. Common examples of this group are grasshoppers, beetles, and caterpillars.

*Group II.*—This includes all insects in that stage of their development in which their mouth-parts are formed for sucking. These insects obtain their food by thrusting the beak below the surface of the plant or animal upon which they feed and sucking its juices, but they do not swallow any of its tissue; hence, poison placed upon the surface of the plant-food would not be taken into the stomach by the insects of this

group. Plant-lice, scale insects, mosquitos, flies, etc., are examples of Group II.

The student should have already observed that an insect, according to the form of its mouth-parts, may in one stage of its development belong to one of these groups, while in another stage it belongs to the other—as, the tomato-worm, the larval stage of the sphinx-moth, which belongs to Group I., while the adult stage, the moth, belongs to Group II.

## VII. Preventives.

A small amount of time and labor spent in preventing insects from becoming established on the farm is often of more value than a great amount spent in trying to destroy them.

1. *Removal of Débris.*—By the prompt removal and burning of all dying or diseased branches, trees, or plants, decayed fruits, and general débris, many insects, as well as their eggs, will be destroyed. While if such material is allowed to remain, it will afford protection for insects during their hibernating and breeding seasons, thus promoting the development of overwhelming numbers.

2. *Change of Crops.*—If an insect pest makes its appearance in a field of grain, one may prevent its devastation the following year by planting the field in some other crop upon which the insect does not feed. For example, the Hessian fly may be observed in a field of wheat.

The following year the development of the Hessian fly in this field may be prevented by putting in a crop upon which it does not feed—as, corn or clover.

**VIII. Insecticides.**

In general, insecticides also are divided into two groups.

*Group I.—Poisonous Insecticides*, or those that kill by being taken into the stomach of the insect. The principal poison in this group of insecticides is arsenic in some form.

Paris green is the most common, and if unadulterated is a very effective arsenical insecticide. It is prepared as follows:

| | |
|---|---|
| Paris green | 1 pound |
| Quicklime | 1 pound |
| Water | 100–300 gallons |

Mix thoroughly, and strain the mixture through a gunny-sack or sieve. The purpose of the lime is to render any free arsenic in the Paris green insoluble, since soluble arsenic would poison the tissue of the plant. It must be remembered that the particles of arsenic are held in suspension and not in solution; hence, the mixture must be kept well stirred while being applied. In spraying plants with tender foliage—as, the peach and plum—the Paris green mixture should be diluted.

Scheele's green differs from Paris green in

that it does not contain acetic acid, and in the per cent. of arsenic. It has the advantages of being held longer in suspension, as it is a finer powder, and of costing only about half as much.

Home preparation insures purer and better arsenical spraying mixtures—as, arsenite of soda and arsenate of lead.

| | |
|---|---|
| White arsenic | 1 pound |
| Sal soda | 4–5 pounds |
| Water | 2 gallons |

Mix the above ingredients and boil until clear —about fifteen minutes. Add enough water to replace that which boiled away. This forms a stock solution which should be placed in Mason jars, labeled poison, and kept until needed. This stock solution is used similarly to Paris green. Since it is soluble in water, and hence would damage the foliage, it is prepared for use by mixing two quarts of the stock solution and eight or ten pounds of freshly slaked lime with one hundred gallons of water.

Arsenate of Lead.*—This insecticide has several advantages over the others just mentioned: (1) it can be used in stronger solutions and in larger quantities without injuring tender foliage, since it is absolutely insoluble in water; (2) it will remain longer in suspension; (3)

* Commercial arsenate of lead sold under the name of disparene, is said to be perfectly reliable. It comes in paste form. and sticks on the foliage well.

being white, it can be more readily seen on the foliage, thus indicating what has and what has not been sprayed. It is made as follows:

| | |
|---|---|
| Arsenate of soda | 4 ounces |
| Acetate of lead | 11 ounces |
| Water | 25–100 gallons |
| Glucose | 2 quarts |

Dissolve the acetate of lead in a *wooden* bucket of warm water, and the arsenate of soda in another bucket of warm water. When thoroughly dissolved, pour both into the quantity of water to be used, according to the strength of the poison desired, at the same time stirring rapidly. If two quarts of glucose be added, the spray will not be so easily washed off by rains.

London purple is not to be depended upon, since it is a product of dye-houses, and its chemical composition varies. It is also injurious to foliage, since it contains a large per cent. of soluble arsenic.

In applying any of the arsenical mixtures, the spraying should not be continued until the water drips from the foliage, as the fine particles of poison are carried away in the drops instead of being left upon the leaf by evaporation after a less quantity is used.

*Group II.—Contact Insecticides*, or those that kill by contact with the body of the insect.

These may be effective in two ways, either by

penetrating the breathing pores and suffocating the insect or by corroding the body.

(1) Kerosene Emulsion.—Of the contact insecticides, kerosene emulsion is one almost universally used by Agricultural Experiment Stations.

The emulsion formula:

| | |
|---|---|
| Soap.............................. | ½ pound |
| Soft water.......................... | 1 gallon |
| Kerosene .......................... | 2 gallons |

The best soap for this purpose is whale-oil soap, though ordinary soft soap or hard soap will answer. The soap should be shaved into the water and thorougly dissolved by heating. When boiling hot, pour the solution into the kerosene, *away from the fire*, and churn vigorously about ten minutes by pumping the liquid back and forth with a force-pump until it resembles buttermilk. The emulsifying will increase the bulk about one-third; hence, the emulsion should not be prepared in too small a vessel.

If tightly sealed, this stock solution will keep for some time. When wanted, dilute with ten to twenty parts of water. If too strong, the kerosene will injure tender foliage. Apply with a spray-pump (Fig. 102) to the infested plants. The emulsion must come in contact with the body of the insect, so that the kerosene may penetrate the breathing pores and suffocate the

insect. The soap also tends to clog the breathing pores.

(2) Tobacco in various forms is a useful insecticide. Its use is especially recommended for house plants, greenhouses, gardens, and orchards. As a spray, it is prepared by steeping the stems or refuse tobacco, and using the tea in a diluted form. It may be applied to the soil around plants with infested roots.

FIG. 102.—A BUCKET SPRAY.

Tobacco dust or stems is an excellent preventive or remedy when scattered about the floor under benches in greenhouses. It is doubly useful when scattered about on the surface of the soil around plants, since it is rich in potash, and acts as a fertilizer as well as an insecticide.

Tobacco Smudge.—This is an especially good remedy in the greenhouse, or in places where the smoke can be confined. The smudge is made by *slowly* burning moistened tobacco, taking care that it does not burst into flame. If only a few plants need to be smoked, they may

be placed under a large box with the smoking tobacco. Care should be taken not to allow the plants to be too long exposed to the strong fumes, or the foliage will be damaged; hence, it will be necessary to repeat the smoking.

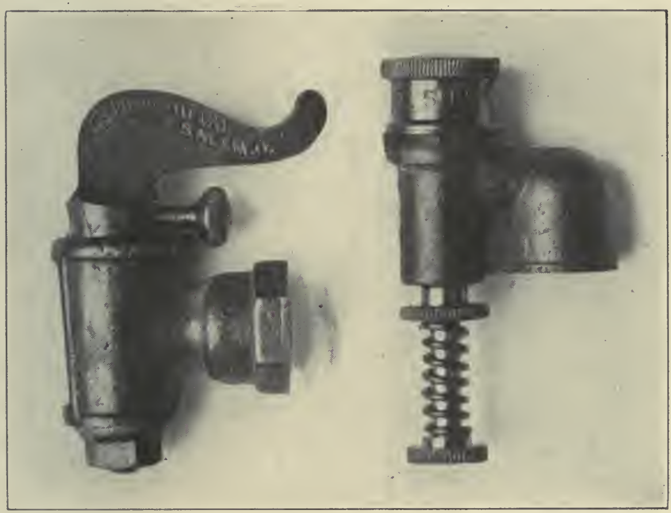


FIG. 103.—THE BORDEAUX NOZZLE.

Carbon bisulphide is especially adapted for use in storehouses, seed-boxes, museum-cases, etc., or as a remedy for underground insects, such as borers and root-lice.

It is a colorless, mobile, and a very volatile liquid. It is not only *very inflammable, but extremely poisonous;* therefore, *great caution* should be taken in using this insecticide. Under no condition should a lighted lamp, or a

cigar, or even a spark of fire, be brought near the fumes.

For storehouses, bins, etc., place the liquid in small, shallow dishes. These should be placed near the top of the bin, since the fumes of carbon bisulphide are heavier than air. This bin should be kept tightly closed for twenty-four to forty-eight hours, and then *well ventilated.* The amount of the liquid used should be in the proportion of one pint to one thousand cubic feet of space. For destroying root pests, small vertical holes should be made in the soil around the plant. Into each hole pour a teaspoonful of the carbon bisulphide and cover at once. Carbon bisulphide is also useful in protecting furs and clothing, since it volatilizes and leaves no stain. The odor is so disagreeable and penetrating that the clothing must be well aired for several days before wearing.

Of the contact insecticides that kill by corroding the body of the insect, those most commonly used are lime, soap, and carbolic acid. These are effective on soft-bodied insects, lime being, perhaps, the most important. Lime is useful both as a preventive and a remedy. It may be applied dry as a dust or as a whitewash.

Some of the contact insecticides—as, kerosene emulsion and carbon bisulphide—are equally effective upon biting and sucking insects, since they kill by suffocation.

### IX. Study on Spraying.

EXERCISE 13—(*a*) From the formulas given, compute the amount of each material required to make one-half gallon of some one arsenical spray—as, Paris green—and one of the contact insecticides—as, kerosene emulsion—and carefully prepare each.

(*b*) Spray some plants infested with caterpillars or slugs—as, the tomato-worm or the rose-slug, and other plants infested with plant-lice—with *each* of these insecticides prepared, and watch results.

(*c*) To be absolutely sure of these results, place a portion of the plants infested by each of these insects experimented upon in each of two breeding-jars, placing that portion sprayed with Paris green in one jar and that sprayed with kerosene emulsion in the other. Label each, and note the effect of each spray upon each kind of insect.

(*d*) Did the Paris green affect all of them the same? Examine the mouth-parts of each insect experimented upon and explain the action of the poison.

(*e*) Did the kerosene affect all alike? Explain.

### X. Natural Enemies.

Among the natural enemies of insects are birds, predaceous ‡ insects, toads, spiders, etc. Few persons realize the extent of the work done by these natural enemies in exterminating noxious insects. Particularly is this true of the birds and predaceous insects.

1. *The Birds* to which we so begrudge our fruit and grain are more than compensating us for this loss by keeping in check insects that would otherwise increase with such rapidity as to endanger the entire crop of orchard or field.

Of the birds of the open field the farmer has no better friend than the meadow-lark. It is unrivaled as a destroyer of injurious insects.

The stomachs of two hundred and thirty-eight meadow-larks, collected from twenty-four different States, and in every month of the year,

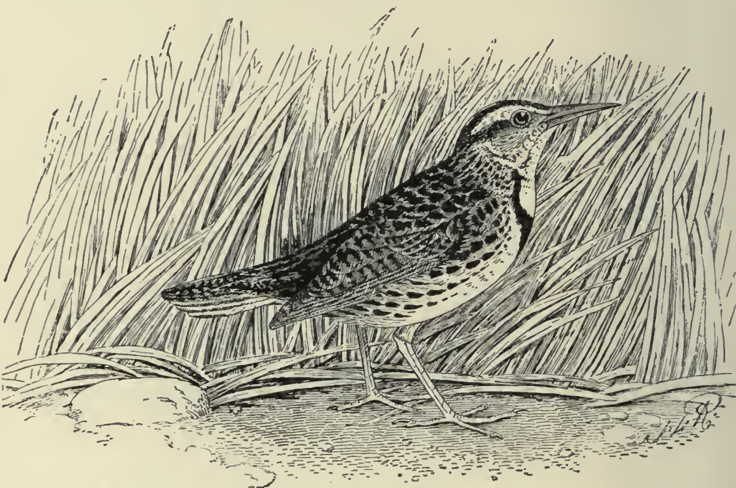


FIG. 104.—MEADOW-LARK (*Saturnella magna*).
(United States Department of Agriculture.)

examined by the United States Division of Entomology, showed that 72 per cent. of the food of these larks was insects, while only 27 per cent. was vegetable matter.

The unassuming little house-wren is one of the most useful birds in destroying insect pests.

Actual examination of the contents of the stomachs of wrens by the Division of Entomol-

ogy at Washington shows that 98 per cent. of the food of the wren consists of injurious insects.

Many other birds of wide geographical distribution are *recognized* as the farmer's friends;

FIG. 105.—HOUSE WREN (*Troglodytes aedon*).
(United States Department of Agriculture.)

among them are the robin, oriole (Fig. 117), mocking-bird, brown thrasher, chickadee, and catbird.

But there is another class of birds which is much persecuted because the farmer errone-

ously considers them his enemies. To this class belong the crow, the blackbird, and many species of hawks and owls.* Examination of the stomach contents of many of these birds has proven that they are more beneficial than harmful, destroying many insects as well as injurious rodents, such as mice and gophers.

Again, some birds eat more or less *weed seed* throughout the year, even when insects are abundant. But their work practically extends from early autumn until late spring. During cold weather most of the birds about the farm feed extensively upon seeds. It is not uncommon for a crow blackbird to eat from thirty to forty seeds of smartweed or bindweed, or a field-sparrow one hundred seeds of crab-grass, at a single meal. In the stomach of a Nuttall's sparrow were found three hundred seeds of amaranth, and in that of another three hundred seeds of lamb's-quarters; a tree-sparrow had consumed seven hundred seeds of pigeon-grass, while a snowflake from Shrewsbury, Mass., which had been breakfasting in a garden in February, had picked up one thousand seeds of pigweed.

Among the weeds which are troublesome in fields, especially among hoed crops, may be mentioned ragweed (*Ambrosia artemisiæfolia*), several species of the genus Polygonum, includ-

* *Year-book*, 1897.

FIG. 106.—FOUR COMMON SEED-EATING BIRDS.

*a*—Junco. *b*—White-throated Sparrow. *c*—Fox-sparrow. *d*—Tree-sparrow.

ing bindweed (*P. convolvulus*), smartweed (*P. lapathifolium*), and knotweed (*P. aviculare*), pigweed (*Amarantus retroflexus* and other species), nut-grass and other sedges (*Cyperaceæ*), crab-grass (*Panicum sanguinale*), pigeon-grass (*Chætocloa viridis*) and (*C. glauca*), lamb's-quarters (*Chenopodium album*), and chickweed (*Alsine media*). Every one of these weeds is an annual, not living over the winter, and their seeds constitute fully three-fourths of the food of a score of *native* sparrows during the colder half of the year. Prof. F. E. Beal, who has carefully studied this subject in the upper Mississippi valley, "has examined the stomachs of many tree-sparrows and found them entirely filled with weed seed, and concluded that each bird consumed at least a quarter of an ounce daily Upon this basis, after making a fair allowance of the number of birds to the square mile, he calculated that in the State of Iowa alone the tree sparrow annually destroys about 1,750,000 pounds, or about 875 tons, of weed seed during its winter sojourn." *

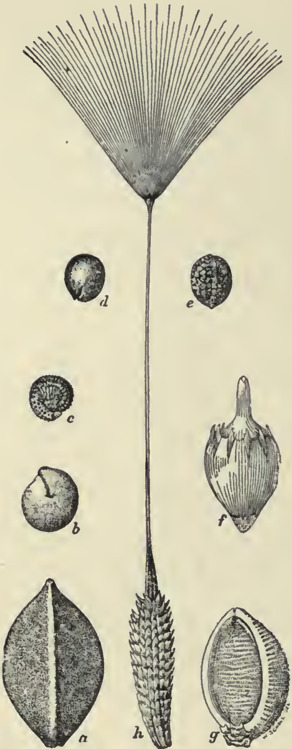
On a farm in Maryland "tree-sparrows, fox-sparrows, whitethroats, song-sparrows, and snow-birds fairly swarmed during December in the briers of the ditches between the corn-fields. They came into the open fields to feed upon

* Quoted from the *Year-book*, 1898: "Birds as Weed Destroyers."


From Year-book, 1898.

FIG. 107.—FOUR COMMON WEEDS, THE SEEDS OF WHICH ARE EATEN BY BIRDS.

*a*—Amaranth. *b*—Crab-grass. *c*—Ragweed. *d*—Pigeon-grass.




Year-book, 1898.

FIG. 108.—WEED SEEDS COMMONLY EATEN BY BIRDS.

*a*—Bindweed. *b*—Lamb's-quarters. *c*—Purslane. *d*—Amaranth. *e*—Spotted spurge. *f*—Ragweed. *g*—Pigeon-grass. *h*—Dandelion.

weed seed, and worked hardest where the smartweed formed a tangle on low ground. Later in the season the place was carefully examined. In one corn-field near a ditch the smartweed formed a thicket over three feet high, and the ground beneath was literally black with seeds. Examination showed that these seeds had been cracked open and the meat removed. In a rectangular space of eighteen square inches were found 1,130 half seeds and only two whole seeds. Even as late as May 13 the birds were still feeding on the seeds of these and other weeds in the fields."* A search was made for seeds of various weeds, but so thoroughly had the work been done that only half a dozen seeds could be found. The birds had taken practically all the

* Quoted from the *Year-book*, 1898: "Birds as Weed Destroyers."

seed that was not covered. The song-sparrow and several others scratch up much buried seed.

No less than fifty different birds act as weed destroyers, and the noxious plants which they help to eradicate number more than threescore species. Some, the blackbirds, the bobolink, the dove, and the English sparrow, in spite of their grain-eating proclivities, do much good by consuming large quantities of weed seed. Horned larks, cowbirds, shore-larks, and grosbeaks also render considerable service, while the meadow-lark is even more beneficial. The "quail as an enemy of insect pests and destroyer of weed seed has few equals on the farm. Goldfinches destroy weeds not touched by other birds, confining their attacks chiefly to one group of plants (the Compositæ), many of the members of which are serious pests. But the birds which accomplish most as weed destroyers are the score or more of native sparrows that flock to the weed patches in early autumn and remain until late spring. Because of their gregarious and terrestial habits, they are efficient consumers of the seeds of ragweed, pigeon-grass, crab-grass, bindweed, purslane, smartweed, and pigweed (Fig. 106). In short, these birds are little weeders whose work is seldom noted, but always felt." *

* Quoted from the *Year-book*, 1898: "Birds as Weed Destroyers."

When one considers, then, that the greater per cent. of the food of birds is composed of insects, and that of the vegetable material they consume a large per cent. is weed seed, and that they obtain fully one-half of the grain they do eat from the waste of the feed-yard and other places, and this largely in the winter months,

FIG. 109.—"LOOK OUT!"

when insects are scarce, it will be realized that *the best and cheapest means of keeping insects in check is the encouragement and protection of birds.*

It would be cheaper to allow the birds a *portion* of the grain or fruit than to allow the insects to take *all*, which would happen

in a few years if the birds were exterminated.*

"What! would you rather see the incessant stir
Of insects in the windrows of the hay,
And hear the locust and the grasshopper
Their melancholy hurdy-gurdies play?
Is this more pleasant to you than the whir
Of meadow-lark, and her sweet roundelay,
Or twitter of little field-fares, as you take
Your nooning in the shade of bush and brake?

"You call them thieves and pillagers; but know,
They are the winged wardens of your farms,
Who from the cornfields drive the insidious foe,
And from your harvests keep a hundred harms;
Even the blackest of them all, the crow,
Renders good service as your man at arms,
Crushing the beetle in his coat of mail,
And crying havoc on the slug and snail."

—*The Birds of Killingworth*, LONGFELLOW. here

2. *Predaceous Insects.*—Predaceous insects, or those that prey upon or eat other insects, are also helpful to the farmer.

(1) SPECIFIC EXAMPLES.—Among the most useful of these insects are several species of ladybugs (*Coccinellidæ*).

Both the adult and larval forms feed upon

* It would be a profitable investment to plant out some Russian mulberry-trees on purpose for the birds, or to grow in waste places and corners such plants as hemp and sunflowers, allowing them to stand throughout the winter as supplies for the birds when food is scarce.

plant-lice and scale insects. The ladybugs are small, rather pretty, turtle-shaped beetles nearly always bright colored (orange or red), with jet black spots upon them, or black with white, red, or yellow spots (Fig. 110). This bright color is a warning to the birds that these bugs are unpleasant to the taste; hence, they are seldom eaten by the birds. The larva is equally protected by its terrifying appearance, since it is covered with long or sharp spines (Fig. 110 *a*).

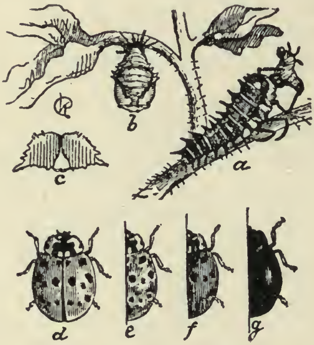



FIG. 110.—*Anatis 15-punctata*, Say.
(After Riley.)

The ladybugs are very common, and are found upon plants infested with plant-lice and scale insects (Fig. 111). The fruit growers of California prevented the destruction of their orchards by importing a species of ladybug from Australia to prey upon these scale insects.*

But there are enemies in the camp: three species of ladybugs are injurious to plants. One species (Fig. 112), in both larval and adult stages, devours the leaves, flowers, and green pods of the bean. Another species feeds upon

* The United States Division of Entomology has imported a Chinese ladybug to prey upon the San José scale.

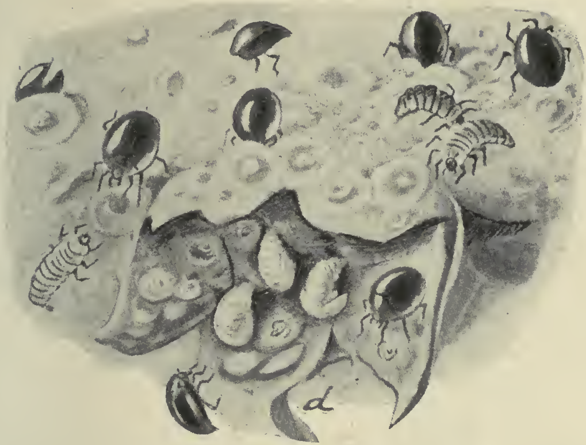
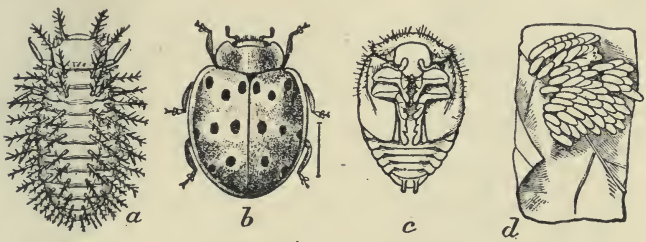



FIG. 111.—LADYBUG AND LARVA PREYING UPON SCALE INSECTS INFESTING A PEAR.

(After Howard and Marlatt, Division of Entomology, Department of Agriculture, Washington, D. C.)

squashes, melons, and cucumbers. This beetle is yellowish in color with big black spots, and is slightly pubescent.‡ The larva is also yellow and covered with forked spines.

Lace-winged Fly.—Another strong ally in fighting our insect foes is the common lace-




Year-book 1898.

FIG. 112.—*Epilachna corrupta.*

*a*—Larva. *b*—Beetle. *c*—Pupa. *d*—Egg mass. All about three times natural size.

winged fly, or Aphis lion (Fig. 113, *a*). It is a beautiful little creature, with brown antennæ and large, lustrous, golden eyes. Its body is of

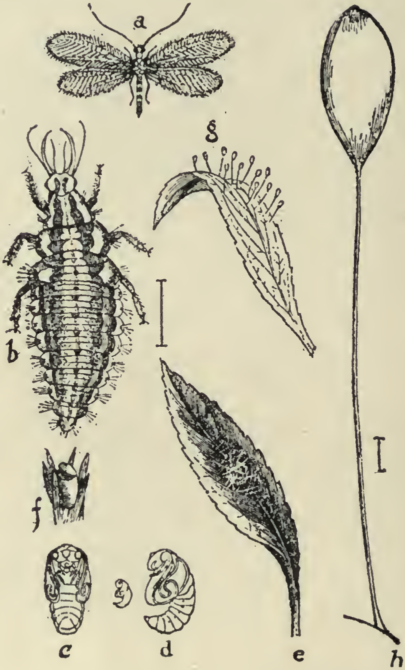



FIG. 113.—CHRYSOPA SPECIES.
(After Brehm.)

a pale green color, as are also its wings of delicate lace. Its attractive appearance, however alluring to the birds, is protected by a disagreeable odor. The eggs, laid in clusters, each egg upon a white, threadlike stalk, look like a diminutive grove (Fig. 113, *g*). This stalked

arrangement is to prevent their being eaten by larvæ, not only of other insects, but of those of their own family, for they are veritable cannibals. The larvæ (Fig. 113, *b*) are as ugly as the adult is beautiful. They are active, spindle-shaped little fellows with crescent-shaped mandibles, which never seem to tire of piercing to death all insects they can capture; but they are particularly destructive to plant-lice (aphides), and for this reason are often called aphis lions. They hold their prey between the tips of their mandibles, and suck the juices through the long tubes formed by a groove along the under side of each mandible and the slender maxilla which fits into it. When this larva reaches its growth it rolls itself into a ball and spins a cocoon of snowy white, from which it comes forth through a circular lid (Fig. 113, *f*) a wondrously changed creature—the dainty lace-winged fly.

FIG. 114.—ICHNEUMON-FLY DEPOSITING AN EGG WITHIN COCOON.

(Slightly magnified.)

Another group of our insect friends is the parasitic Hymenoptera, such as the ichneumon-

flies, Chalcis flies, and braconids. These generally lay their eggs in or on the body of the larva of other insects, but sometimes they deposit them in the adult, the pupa (Fig. 114), or even the egg. When the eggs hatch, the larvæ feed upon the substance of the host, thus destroying it, together with all of its posterity, which in a few years might have been countless.

One genus of the ichneumon-flies which is often mistaken for an enemy of plants is the *thalessa*, a yellow or black (according to the species) insect, with a long, slender, though powerful, ovipositor, with which it pierces into the wood of a tree. It will be found upon examination, however, that the tree is infested with borers (Fig. 122), and that what the ichneumon really does is to deposit its eggs in the nest of the borer, where the larva, when it hatches, fixes itself to the body of the borer, living upon its juices and gradually killing it.

The many species of Chalcis flies, as well as the ichneumon, are parasitic upon a great number of different insects, one species feeding upon the chrysalis of the cabbage-butterfly.

(2) Exercise 14.—(*a*) As many kinds of these insects as can be obtained should be placed in the breeding-jars and watched through their development.

(*b*) Experiment with the food of these insects in different stages of their development to ascertain in what stage they are predaceous and what insect forms they will eat.

(*c*) It will be interesting and instructive to place the larva and the adult forms of the ladybug, and of the lace-winged fly in the breeding-jars, and supply them with portions of plants infested by aphides, and watch what takes place.

(*d*) In which of these stages did your specimen of ladybug devour the plant-lice? How?

(*e*) In which of these stages did your specimen of lace-winged fly devour the plant-lice? How?

## XI. Specific Examples of Injurious Insects.

1. *Plant-lice* are among the most familiar and most annoying of the insects injurious to plants. The family includes many species, all of which are small, the largest measuring only one-fourth inch in length. Most of those we see are wingless, but some of the common species have two pairs of transparent wings. Our most common species of plant-lice are green or black, but others are red, brown, or yellow. The beak is three-jointed. It is not coiled up like that of the butterfly, but is attached to the head by a hinge, and is bent up against the under side of the body when the insect is not feeding. They feed upon the buds, leaves, and tender growing stems or roots of plants, and in such immense numbers as to often do much damage.

Exercise 15.—It will be easy to find colonies of these plant-lice upon crysanthemums, cherry, or plum sprouts, or even roadside weeds.

(*a*) Let the class watch them closely, taking care not to disturb them. What other insects do you see among them? Do you find two tiny tubes projecting from the

terminal segment of the abdomen of the plant-louse? Is there a drop of honeydew on the tops of these tubes? What do you find ants doing with this honeydew? If no honeydew is present, observe the ants stroke these plant-lice with their antennæ. Do they then obtain the honeydew (Fig. 115)? This process is commonly spoken of as the "ants milking their cows." Bees and wasps also like this honeydew.

Ants care for the plant-lice in many ways, protecting their eggs and carrying the lice to the roots, upon which they feed.

(*b*) Do you find any enemies in the colony?

(*c*) Kerosene emulsion is, perhaps, the best remedy. Why?

(*d*) Will the Paris green spray kill them? Explain.

2. *The Rose-slug* (*Monostegia rosæ*) is a soft-bodied larva, green above and yellowish below, which eats the surface of the rose leaves, leaving only the framework. When full grown the larva buries in the ground. The adult is a tiny black fly with dull-colored wings, and with the first and second pair of legs grayish. There are two broods a year (one in early summer and one in late summer), the second brood pupating in the ground over winter, and the adult emerging in the spring. Either Paris green or kerosene emulsion will form an effective remedy. Why?

3. *Tent-caterpillar.*—There are several species of tent-caterpillars; but only two, the apple tent-caterpillar (*Clisiocampa americana*), and the forest tent-caterpillar (*Clisiocampa*

*disstria*) are common in the United States east of the Rockies. The adult form of the *C. americana* is a rather small, rusty brown moth, with oblique, pale yellow lines across the four wings (Fig. 116).

The eggs are laid in summer in a circular

FIG. 115.—ANTS MILKING PLANT-LICE.
(After Figuir.)

band about a twig. This band of eggs (Fig. 116, *c*) is protected from the weather by a sticky substance with which the parent moth coats them over. The following spring, just before leaf buds open, these tiny caterpillars come

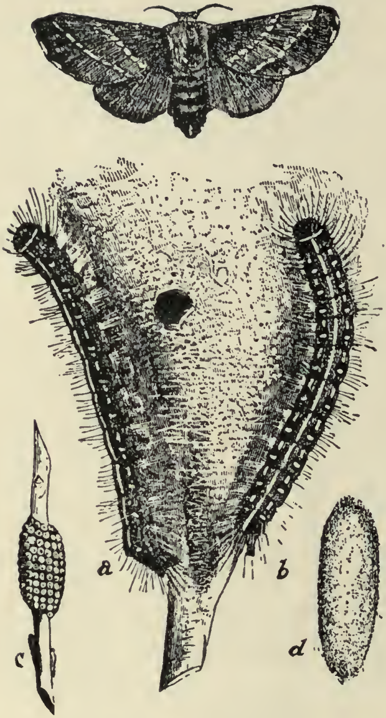



FIG. 116.—AMERICAN TENT-CATERPILLAR (*Clisiocampa americana*).*

*a* and *b*—Full-grown worms on the outside of the tent. *c*—Egg-mass, with the gummy covering removed. *d*—Cocoon, containing the chrysalis. Above all, the moth.
(After Riley.)

* Our Western species *Clisiocampa fragilis*) resembles the above so closely that the figure serves equally well for it.

forth to feed upon the buds, and soon the colony, for they are social beings, spins a silken web, or "tent," on the fork of a branch (Fig. 116, *a* to *b*), to which the caterpillars retire at night and in cold and stormy weather. They grow rapidly, and greedily devour the leaves as they come out, doing much damage.

When the caterpillars are grown they are about two inches long and covered with hairy bristles. They are black with a white stripe down the median line, and with short yellow lines and pale blue spots on each side (Fig. 116, *a* and *b*). When they have reached their growth they leave the tree, seek

shelter on the ground under boards, bark, etc., and spin a silken cocoon (Fig. 116, *a*), from which, after a few weeks, the moth emerges.

The apple and wild cherry are the trees most usually attacked by these caterpillars, but they

FIG. 117.—BALTIMORE ORIOLE ATTACKING THE NEST OF THE AMERICAN TENT-CATERPILLAR.

have been found upon the peach, rose, and other members of this family of plants, as well as upon forest and shade trees.

Bacteria and parasitic ichneumon-flies, as well as many birds, such as cuckoos, blue jays, crows,

and orioles (Fig. 117), serve as natural checks to these insects, but they are by no means sufficient to prevent them from doing great damage.

Every farmer should take prompt measures to destroy them at their first appearance upon his trees. This may be done effectively by spraying the foliage with arsenate of lead, or Paris green, or by collecting them in their tents early in the morning or late in the evening. This may be done by thrusting into the tent the end of a long pole, into which has been driven two or three nails, and turning the pole round and round so as to twist the web about it. The caterpillars should then be burned or crushed.

FIG. 118.—FOREST TENT-COCOONS IN APPLE LEAVES.

4. *The Forest Tent-caterpillar* (*C. disstria*) is very like the American tent-caterpillar in appearance and habits. The markings upon the wings of this moth are dark instead of light, while in the caterpillar (Fig. 119) the median line is

marked with a row of white spots instead of a continuous line of white, as in the *americana*.

In the colonies or masses which they form

FIG. 119.—FOREST TENT-CATERPILLARS FEEDING UPON ELM LEAVES.

when not feeding there is a more or less distinct web underneath them, but it does not form a complete covering above them, as in the *americana*. They not only eat away consider-

able portion of the leaf, but they cut it in two, so that the end falls to the ground; in this way the damage is doubled (Fig. 119). To this is also added the injury done to the foliage by binding up the leaves (Fig. 118) for the attachment and the protection of the cocoon.

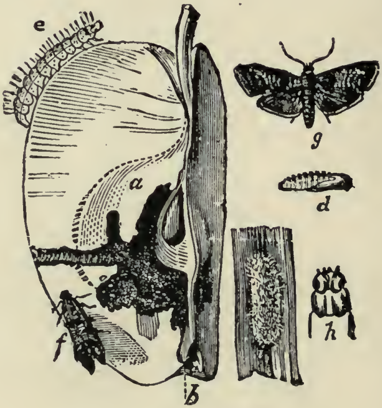



FIG. 120.—CODLING-MOTH.

*a*—Injured apple.—*b*—Place where egg is laid. *e*—Larva. *d*—Pupa. *i*—Cocoon *g*, *f*—Moth. *h*—Head of larva. (After Riley.)

They may be destroyed by spraying the foliage, at the *first appearance* of the caterpillar, with arsenate of lead or Paris green. Both the forest and the apple tent-caterpillars often drop to the ground, and they may be prevented from crawling back up the trunk by banding the base of the tree with a strip of cotton or of "tanglefoot" fly-paper. This should be closely

applied to the trunk about a foot from the ground, allowing the caterpillars to collect below the band, when they may be removed and destroyed, or sprayed copiously, and, if need be, repeatedly, with kerosene emulsion.

5. *The Codling-moth* (Fig. 120).—Comstock says: "This is the best-known and probably the most important insect enemy of the fruit grower." The adult is a tiny gray moth (Fig. 120, *g*). Its front wings are sometimes tinged with pink. These wings have a large brown spot near the edge, crossed by metallic, bronzy bands.

The eggs are laid each in the blossom end of an apple, just as the petals are falling. In a few days the larva hatches, feeds a little upon the surface of the apple—for a few hours or a day—then eats its way into the center of the apple, where we find it as "a little white worm."

The larvæ may be destroyed before they do any damage by spraying the trees with Paris green or arsenate of lead, just as the blossoms fall, and before or at the time the larvæ hatch. At this time the fruit stands with blossom end up, and the poison will reach the place where the larva hatches. It is necessary to repeat this spraying in a few days or a week, the time depending upon whether it is dry or rainy weather. A large percentage of the apples which drop prematurely will be found to contain these larvæ.

The larva remains in the apple only a short time after it drops; then it crawls out (Fig. 120, *e*) and seeks some secluded place—as, under bark, boards, etc.; hence, if the apples are removed and burned, or fed to hogs *at once*, many of last year's larvæ will be destroyed, and thus the number of adults left over for spring breeding greatly lessened.

6. *The Borers* are another group of insect pests which, owing to their habits and life history, must be combated in an altogether different manner.

This group includes the many species of borers. The remedies for many of these borers are the same, but the *time and methods* of applying them depend upon the habit of the particular species in question. Each is a study in itself, and one must know something of the habits and life history of each particular species which he would successfully combat. On account of limited space, but one example of borers can be given.

(1). Example.—The Round-headed Apple-tree Borer (*Saperda candida*).—The presence of these borers may be detected by the sickly appearance of the tree and by the sawdust from their gnawings, which is pushed out of their tiny canals (Fig. 122). It takes nearly three years for these insects to complete their life-cycle.

In June or July the eggs are laid singly at the

base of the trunk, under a loose scale of the bark or in a little incision made by the mandibles. In about two weeks the larva is hatched, and at once begins to gnaw into the sapwood and inner bark, where it remains for a year, making "disc-shaped mines," in the lower part of which it

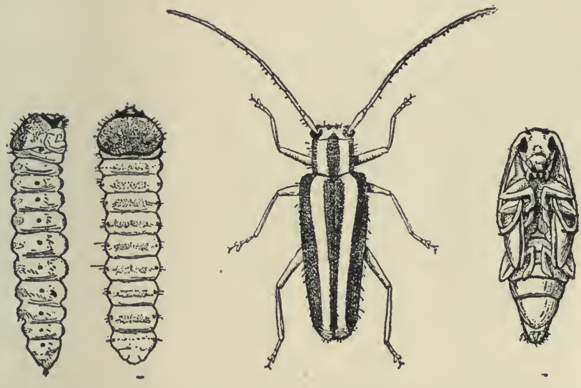


FIG. 121.—ROUND-HEADED APPLE-BORER (*Saperda candida*, Fab.). (After Division of Entomology, United States Department of Agriculture.)

spends the winter. The following summer it again works in the sapwood, and in the third season "cuts a cylindrical passage upward into the solid wood" (Fig. 122). It afterward gnaws out toward the bark, sometimes going on through the tree.* "It changes to a pupa (*g*) near the upper end of its burrow in May, and emerges as a beetle in June."

(2) PREVENTIVES.—Nature furnishes many

* Comstock's *Manual for the Study of Insects*, p. 573.

helpers in keeping boring insects in check—such as woodpeckers, ichneumon-flies, Chalcis flies, etc. In combating all kinds of borers an ounce of prevention is, indeed, worth more than a pound of cure. *Prompt removal of all dead or dying trees is a necessary measure.* The most effective preventive is to wrap the base of

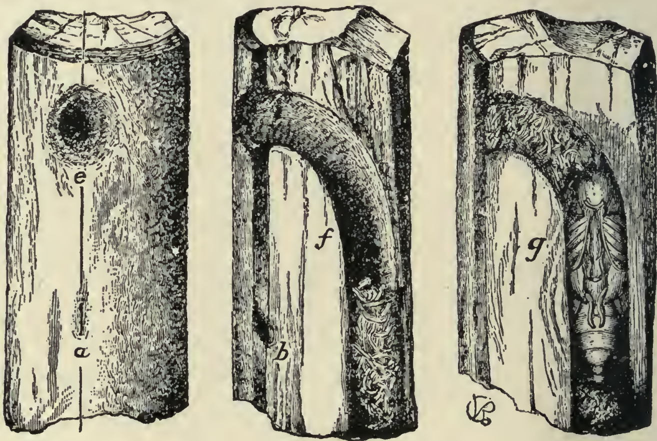



FIG. 122.—*Saperda candida*, Fab.

*a*—Puncture in which egg is laid. *b*—Same in section. *e*—Hole from which beetle has emerged. *f*—Same in section. *g*—Pupa in its cell. (After Riley.)

the tree trunk for about a foot and a half with wire gauze netting, or, what is cheaper, wooden wrappers obtained from box and basket factories. They should be pushed down into the ground so that the beetle cannot get under to lay its eggs, and the tops should be tightly filled in with cotton batting to keep them out. The

wooden wrappers also protect the tree from sun-scald and from rabbits.

A very effective remedy, which has been tested and recommended by Prof. J. M. Stedman, State Entomologist for Missouri, is an alkali wash made as follows: "Dissolve as much common washing soda as possible in six gallons of water; then dissolve one gallon of ordinary soft soap in the above, and add one pint of crude carbolic acid and thoroughly mix; slake a quantity of lime in four gallons of water, so that when it is added to the above the whole will make a thick whitewash; add this to the above and mix thoroughly, and finally add one-half pound of Paris green or one-fourth pound of powdered white arsenic and mix it thoroughly in the above."

This wash, of course, has no effect upon the larva when it is inside of the bark, but it prevents the insect from laying its eggs upon the bark, or if the egg is already present it kills the larva before it enters the tree. As much loose bark as can be taken away without injuring the tree should be removed, and every crack and crevice filled with the wash by rubbing hard with the scrubbing-brush in applying it. The wash should be applied early in June and again early in July.

## *B.*—INJURIOUS FUNGI.

The enemies of plants are not restricted to animal forms, but many of them are low forms of plants. Parasitic fungi, or low forms of plants which do not have the power to live upon unorganized food as green plants do, feed upon the tissues of living or dead animals or plants, and often do a *great amount of damage.* The fungi, which feed upon *living plants* greatly concern the agriculturist. Millions of dollars are lost yearly by the damage caused by parasitic fungi.

The parts of the fungus are the mycelium (the vegetative threads which ramify the tissues of the host), and the minute spores, or reproductive organs, the function of which is similar to that of the seed of higher plants.

### I. Specific Examples.

Space permits only the brief mention of a few of the numerous fungi, but it is hoped that this may be sufficient to give the student a slight idea of their development and the method of combating them.

1. *Brown Rot* (*Monilia fructigena*) (Fig. 123).—This is the familiar rot of the plum, peach, and cherry, first appearing as a small dark spot on the nearly ripe fruit. The ripe spores are easily carried by the wind, and frequently this rot destroys the entire crop. The rot spreads fast if the weather is warm and moist.

Those fruits which touch each other are most easily affected; hence, the importance of thinning the fruit. Another point to be remembered is the fact that the fruits infested by these fungi

FIG. 123.—BROWN ROT (*Monilia fructigena*).

dry up and remain upon the tree, and thus carry the spores over to the next year. These mummified fruits (Fig. 123) should be destroyed or fed to hogs. Frequent spraying with the *diluted*

Bordeaux * mixture (see page 341) will be an effective prevention if done in time.

2. *Black Rot* (*Lœstadia bidwellii*) of the grape (Fig. 124) is a fungous growth which attacks nearly or quite grown grapes, beginning as a dark spot which spreads over the whole grape, making it a purplish brown color. The grape then shrivels, turns black, and is covered with very minute elevations.

FIG. 124.—BLACK ROT (*Lœstadia bidwellii*).

Just before the fruit ripens, or earlier if the weather is warm and moist, this fungous growth is apt to appear, and prompt and frequent spraying should be resorted to. Bordeaux mixture is recommended for earlier spraying; but it stains the fruit, thus injuring its appearance, when it begins to ripen. The ammoniacal copper

* "Since the leaves of the peach and plum are sensitive to this spraying mixture, it should be used only in extreme cases."—WILCOX.

carbonate solution should then be substituted for the Bordeaux mixture. Care must be taken to burn the mummified fruits (Fig. 124).

3. *The Bitter Rot* of apples (*Glœosporium fructigenum*).—This is sometimes called the

Year-book, 1899.

FIG. 125.—GRAPES FROM VINEYARD AFFECTED WITH BLACK ROT. Sprayed and unsprayed.

ripe rot of apples, as it seldom affects the fruit until half or nearly grown, and often effects it even after it is stored.* It first appears as small brown spots which enlarge, and sometimes two or more unite, so that soon the whole fruit is rotted. The fruits may drop off, but often re-

* Unless in cold storage.

main upon the tree and dry up, thus protecting the spores to start an extensive crop the succeeding year.

Every rotten apple, whether on the ground or on the tree, should be destroyed, and all canker spots on the branches or trunk cut out. Spraying with the Bordeaux mixture should be begun the middle of July, and repeated

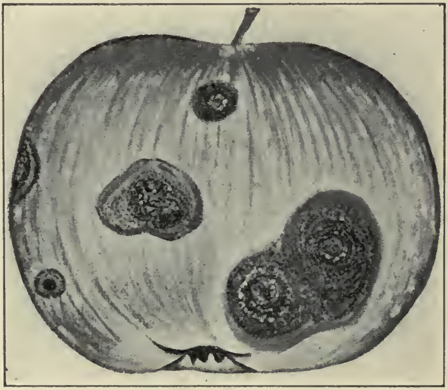


FIG. 126.—AN APPLE ATTACKED BY BITTER-ROT FUNGUS. (After Alwood.)

twice a month or oftener. Substitute for the Bordeaux mixture, as the apple reaches its growth, the ammonical copper carbonate solution.

4. *Apple Scab* (*Fusicladium dentriticum*). —This common and very injurious fungus attacks both foliage and fruit. It is found on the leaves as "sooty" spots. The leaves become yellow and fall. It appears on the fruit as a

brownish scab, often distorting the shape. It does the most damage just at the time of blossoming, and the forming apples drop off. It may be largely prevented by spraying with Bor-

FIG. 127.—APPLE SCAB.
(After Lademan.)

deaux mixture several times in the spring as the blossoms open, and afterward at intervals of two weeks.

**II. Fungicides.**

(1) The best spray for general use as a fungicide is without doubt the *Bordeaux mixture*.

FORMULA FOR LIQUID BORDEAUX.

| | |
|---|---|
| Copper sulphate | 3 to 6 pounds |
| Quicklime. | 3 to 6 pounds |
| Water. | 50 gallons |

The amount of copper sulphate used depends upon the strength of the mixture desired, three

pounds being sufficient for peach-trees in foliage, and six pounds being harmless to dormant trees. Dissolve the copper sulphate in an earthen jar or wooden pail by suspending it in a sack so that it will just touch the water. Hot or cold water may be used. Slake the lime, and *after* it is done slaking add water enough to make a thin paste; strain this through a gunny-sack into a vessel containing twenty-five gallons of water, and stir thoroughly. Mix together the lime and copper sulphate solutions in equal parts.

It is well to add a little of one of the arsenical sprays, since by so doing one may kill both insects and fungi at the same time. It is better to use the Bordeaux mixture when fresh.

*Dust Bordeaux.*—A fine powder which contains copper in the same chemical state that exists in properly made liquid Bordeaux mixture can be prepared by following the directions given below.

Materials required to make seventy pounds of stock powder:

Four pounds of copper sulphate (bluestone).

Four pounds of *good* quicklime.

Two and a half gallons of water, in which to dissolve the copper sulphate.

Two and a half gallons of water, which is to be added to the quicklime.

Sixty pounds of air-slaked lime, which has

been sifted through the fine sieve mentioned below.

A box, about 3 x 3 x 3 feet, into which the material is sifted. The following arrangement will facilitate the sifting and prevent excessive flying about of the fine dust.

A wire sieve made with a cover. The bottom should be of rather stout wire gauze having twenty-five or thirty meshes to the inch. This sieve should fit loosely between the strips on the box, and can be shaken back and forth over the opening without allowing much lime dust to escape.

A wooden frame of 1 x 1 inch strips which fits snugly inside of the sifter, and is covered with fine strainer-wire gauze having one hundred meshes to the inch. This makes a false bottom to the stoutly made sifter, and is used to separate the fine dust of the air-slacked lime and for the final sifting.

A wooden block to rub the material through the coarse sieve.

Two close-woven cotton flour-bags—one slipped inside the other—with which the blue material is filtered.

Directions.—1. Break up into small lumps about seventy or eighty pounds of quicklime, and spread it out so that it will become air-slaked. When slaked and perfectly dry, sift it through the fine sieve (one hundred meshes).

2. Completely dissolve four pounds of copper sulphate in two and a half gallons of water. The easiest way is to suspend the sulphate in a coarse bag just below the surface of the water until it is dissolved.

3. Pour gradually two and a half gallons of water over four pounds of *good* quicklime in such a manner as to slake it to the finest powder and give a good milk of lime solution; let it cool.

4. Put sixty pounds of the sifted, air-slaked lime into a shallow box—one in which the material can be well worked with a hoe or shovel.

5. Pour the well-stirred milk of lime and the copper sulphate solution *at the same time* into a third vessel, and stir until the whole is thoroughly mixed. It will have a deep blue color and be thick. This is so finely divided that it will remain in suspension for hours.

6. Pour this immediately into the double flour-bag; filter and squeeze out most of the water.

7. Empty this wet blue material at once (*do not let it dry*) into the sixty pounds of air-slaked lime, and work it up so that it will be well distributed. If the resulting mixture is too moist, add more air-slaked lime.

8. Rub this through the course sieve *while still somewhat damp*, mix thoroughly, and spread out to dry.

9. When perfectly dry, sift it through the fine-

mesh sieve, crushing all lumps. All of this can be readily made to go through the fine sieve, except the small amount of sand which may be in the four pounds of quicklime. Mix so that the blue copper compound will be perfectly distributed throughout the whole mass.

If it is desired to use an insecticide for canker-worm or codling-moth, one pound of Paris green

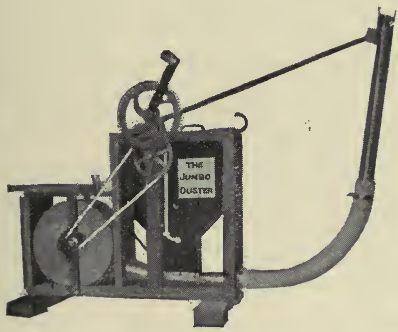



FIG. 128.—JUMBO DUSTER.

may be added to twenty pounds of the dry Bordeaux mixture.

The dust sticks to the trees much better if it is applied when the dew is on the trees or while they are wet just after a rain.

Whether or not this powder, when applied to the leaf wet with dew or rain, will prove as effective as the liquid Bordeaux mixture only experiment will show. Dry fungicides and insecticides are much lighter to handle and can

be applied much more rapidly than those which are applied in water.*

Dust-spraying machines may be obtained from Leggett & Brother, New York City; Kansas City Dust Sprayer Co., Kansas City, Mo.; Ozark Dust Sprayer Co., Springfield, Mo., and others.

2. *The Ammoniacal Copper Carbonate Solution.*—When the fruit is almost ready for market it is advisable to use the ammoniacal copper carbonate solution, as the Bordeaux mixture *stains* the fruit and mars its appearance.

FORMULA

| | |
|---|---|
| Copper carbonate.................... | 5 ounces |
| Strong ammonia........................ | 3 pints |
| Water ............... .............. | 50 gallons |

Add enough water to the copper carbonate to make a thin paste; then pour into it the ammonia and mix thoroughly; then add the water. Use instead of the Bordeaux mixture whenever it is desired to avoid the stain made by the Bordeaux.

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# OUTLINE OF CHAPTER XIII.

## ORNAMENTATION OF SCHOOL AND HOME GROUNDS.

### *A.*—SCHOOL GARDENING.

**I. School-grounds.**

1. *Trees.*
2. *Shrubbery.*

**II. Experimental Garden.**

1. *Preparation.*
   (1) Study on Soil and Seed.
   (2) Preparation of Ground.
2. *Plantings.*

**III. Window-garden.**

### *B.*—LANDSCAPE-GARDENING.

**I. Geometrical Style.**

**II. Natural Style.**

### *C.*—REFERENCES.

FIG. 129.—AGRICULTURAL CLASS, KIRKSVILLE STATE NORMAL SCHOOL.

# CHAPTER XIII.

## ORNAMENTATION OF SCHOOL AND HOME GROUNDS.

### *A.*—SCHOOL GARDENING.

**I. School-grounds.**

These present a difficult problem. A playground must and will be had by the children. Very often this is too small to spare a foot for ornamental purposes, but nooks and corners may be used.

1. *Trees.*—If there is any possible way, let there be a few large shade-trees. It would render the school-room more comfortable, as well as more inviting, to have a tree so placed as to shade the windows upon the south or west side. Surely young trees can be planted on the edge of the street along the school-ground, and properly protected until a good root-system is established.

2. *Shrubbery.*—Instead of a high board fence, clumps of shrubbery may be used. They can easily be arranged so as to form a screen, as well as to make a pretty background for the schoolhouse.

One excursion to the woods will be sufficient to secure abundant material for the year. Many of the pupils will gladly bring a flowering

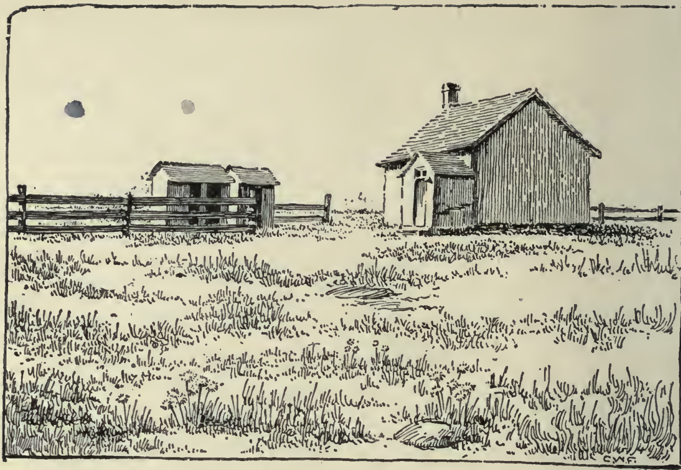

FIG. 130.—A COUNTRY SCHOOL-YARD—BARE AND UNATTRACTIVE.

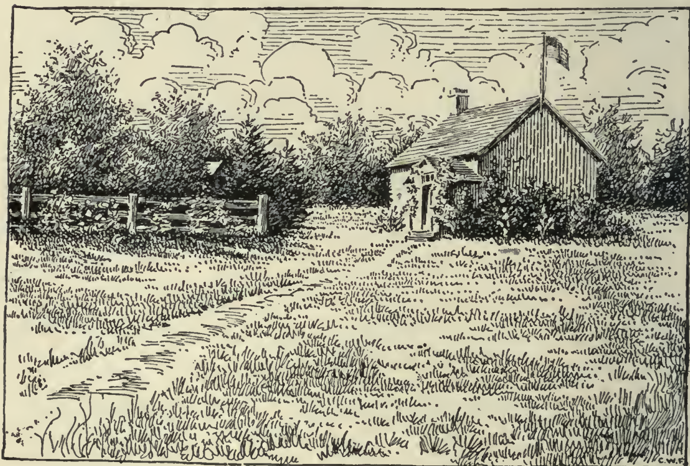

FIG. 131.—THE SAME SCHOOL-YARD IMPROVED BY PLANTINGS OF SHRUBBERY.

It would look still better without the fence. (Bulletin, Cornell College of Agriculture.)

shrub from the home grounds if the teacher will only interest them in this work, and then use taste in arranging the material when it is brought.

**II. Experimental Garden.**

If the school-grounds are ample, a little experimental garden laid out in the back yard will be well cared for by the children if enthusiasm has been rightly instilled and controlled by the teacher.

If the grounds are not large enough to admit of this, *the teacher is urged to secure a vacant lot for this experimental garden.* No doubt it can often be obtained for a small rental, or, perhaps, for a share of the products. If agriculture is to be studied, and it ought to be in some part of the course of study in every school, then *the experimental garden becomes a necessity.*

The school garden should have the hearty support of the children concerned ; without this it will be a failure. A child that has to be forced to take up this work would far better be excused—for the first year, at least. There will be time enough for him to repent when he sees his playmates with fine flowers and vegetables of their own. To gain the hearty support of the children requires only an enthusiastic teacher—one who believes in his work, and has a definite, organized course of procedure.

1. *Preparation.* (1) STUDY ON THE SOIL

AND THE SEED.—About a month or six weeks prior to the work in the open ground, preparatory lessons should be given on the soil and on seed germination. These should include: (*a*) A comparative study of the different types of soils (sand, clay, humus, and loam), as to their color, weight, porosity, size of particles, and power to absorb and retain heat. (*b*) A study of the seed and the conditions governing germination. Some of the principal points to be considered in these lessons are purity and vitality of seeds, the seed-coat, depth of planting, time of sprouting, and effect of light, air, moisture, and heat on germination (see Chapter IX.).

Samples of all the different seeds to be planted in the garden should be carefully examined and tested for purity and vitality, discarding all those that are impure or are slow to germinate. For early planting, seeds of such plants as the tomato, cabbage, and pansy should be started indoors. In every case the child should work out these results for himself by actual experiments or observations. If well done, this work will form an excellent basis for the work in the outdoor garden.

(2) PREPARATION OF GROUND.—The soil for this garden should be thoroughly prepared by plowing and harrowing, independent of the children's work. A certain space of ground should be planned for and assigned to each

child. As a *minimum* this should be 4 x 10 feet, with a path a foot and a half or two feet wide on each side. The measuring should be done by the children, but it will be necessary to measure very accurately, in order that each child may get his rightful share of the ground and that this drill may be practical. Care should be taken not to tramp the ground any more than is absolutely necessary. As the plats are laid off, they should be marked with a stake at each corner. The paths should be determined as soon as possible, and the *passing over the grounds restricted to these.*

Each child should have full charge of his individual garden throughout the term, and be responsible for the general condition of the garden and path. It should be clearly understood at the beginning that any child who is absent twice in succession without a good excuse will forfeit his right to his garden.

*Great care must be exercised by the teacher, lest making the garden* should become *the sole aim* instead of *the development of the child. It must not be forgotten that the latter is the paramount purpose of all school work.* Hence, the teacher should first require careful thought concerning the prospective garden; then the individual tastes of the children should be consulted in selecting and arranging their own plantings.

Now, having decided how and where each variety is to be planted, the ground should be

FIG. 132.—SECOND GRADE CHILDREN PLANTING THEIR GARDENS.
State Normal Training-School, Kirksville, Mo.

well pulverized and marked off by the children. If rows are used they should be from one to three feet apart, according to the character of the plantings.

2. *Plantings.*—The first planting may consist of radishes, lettuce, and onions. These may occupy two-thirds of the ground. The remaining portion should be used for growing flowers; some rather low flowering plants are preferable, such as California poppies, dwarf nasturtiums, verbenas, phlox, and Ageratum. As the first planting of vegetables is removed, a few tomato-plants, cabbage-plants, a potato hill, or some dwarf beans may be put in.

The experimental garden makes possible many lessons in nature. From the plants here grown the child may gain an idea of the entire life history of them: seeds, roots, stems, leaves, flowers, and fruit may be studied. Ample opportunity will be had for the study of "our friends, the birds," and of our insect friends and foes.

The children should compare their gardens with those of their neighbors, and be led to see their mistakes, and, if possible, the reason for them, so they may obtain better results next time. Thus, while training the powers of observation and comparison (and deductive reasoning in the case of *older students*), the children will be also learning practical lessons in growing plants to supply them with food or to adorn their homes, thereby elevating their tastes and enriching their lives.

### III. The Window-garden.

Window-boxes of growing plants (Fig. 133) will add to the attractiveness of the school-room. The difficulty lies in the danger of

FIG. 133.—A SOUTH WINDOW-GARDEN, CONTAINING GERANIUMS, BALLOON-VINES, ASPARAGUS, AND VINCA.

freezing the plants in winter nights; but even if this cannot be prevented, there are three months in the spring and two or three in autumn when the plants may be had, and much can be done in interesting the pupils in this time.

The window-box should be made of inch lumber, about seven inches deep and the width and the length of the window-sill. A strip of oil-

cloth should be put upon the window-sill, and the box supported by blocks or other means, so

FIG. 134.—A NORTH WINDOW-GARDEN, CONTAINING FUCHSIAS, WILD FERNS, MADEIRA-VINES, BEGONIAS, AND AN UMBRELLA-PLANT.

that the air may pass freely beneath it, thus preventing the decay of the window-sill or facing. It is important that the soil be well pre-

pared by thoroughly mixing decayed leaf-mould, garden soil, and sand.

The plants must be studied carefully to find out which love the sunshine and which the shade, or, in other words, which can be grown

FIG. 135.—ROMAN HYACINTHS.

in the south and which in a north window (compare Figs. 133 and 134). Try some of the same kinds in each window and record your results. Try ferns of various kinds, and begonias, umbrella-plants, and Madeira-vines in the north window.

If they can be kept from freezing through the winter, nothing will prove more satisfactory than a box of bulbs. Crocuses, hyacinths (Fig. 135), freesias, and narcissus will require little attention and give good results. The Chinese sacred lily (Fig. 136) is a large and beautiful narcissus, a large bulb of which, if simply placed

FIG. 136.—CHINESE SACRED LILY.
Holly fern in front.

upon sand and pebbles in a deep dish of water, will bloom in a few weeks, and continue to bloom for some time.

Here 4½.

## *B.*—LANDSCAPE-GARDENING.

Landscape-gardening is an art, just as truly as the painting of pictures and the modeling of sculpture; and where means will permit, it is just as essential to have an artist—one whose artistic tastes and ability to interpret Nature

give him the right to the title of "Landscape-gardener"—to design the grounds, choosing a site for and suggesting the form of the house, laying out the roads and walks, and planning the planting of trees, shrubs, and flowers, so as to make one harmonious picture, as it is to have an architect to design the buildings and plan the rooms for the convenience and comfort of the occupants.

Few of us can afford the services of landscape-gardeners, and fewer still are ourselves real artists. What then? Shall our homes be simply shelters from the winter's wind and summer's sun? Mere houses, where we eat and sleep and exist? Or shall they be, so far as it lies in our power to make them, abiding-places of comfort and joy and beauty; places where the eye of the weary mother, as she glances up from her work, may meet the restful view of shrub and tree and sky, all blended into one delightful picture; where the passer-by may receive refreshing glimpses of cooling shade and vistas of beauty half-hidden by the trees or clumps of shrubbery, or catch sight of the gay colors of summer flowers or glorious tints of autumn leaves—dwelling-places which elevate and enrich our lives? If this latter condition is to be obtained, then the finished landscape must first exist in the mind—*i.e.*, be seen in the imagination of the designer, just as the finished picture must be seen by the

painter before he touches his brush to the canvas.

*The Design.*—In the design the landscape-garden must have *unity*—some one dominating purpose throughout the whole, though this purpose need not be manifest to the observer.

*The Grounds* must be seen from various standpoints; they must be considered as viewed both from within and without—from the beauty of their winter form and outline as well as of their summer verdure.

In the site of the house and in the grouping of accessory buildings convenience and comfort must be first regarded, but not alone; for often a beautiful and delightful location *might have been selected* which would have been just as convenient and healthful as the dull or matter-of-fact one which was selected, and which no amount of time and money could ever make the equal of the other.

Hence, it is of the utmost importance that a careful study of the *natural resources* should be made. There is no spot, whether among mountains or at the seashore or on the rolling prairies, which does not have its own original beauty. There will always be something in the contour of the land, in the plant growth, or in the general outlook of the grounds, that will be worthy of serious consideration. There may be massive trees that are impressive by their size and age

which man by one foolish act could destroy, thus undoing what it has taken Nature years to develop. "A tree is a precious inheritance from the past, and should be transmitted to posterity with as keen a sense of its artistic value as though it were a famous picture or statue." *

*The plan* must be specific, and it would be well to make it on paper with pen and ink—planning not so much for the present appearance as for the finished permanent picture; no tree, vine, or shrub of a permanent character should ever be planted without this in mind.

*Styles of Landscape-gardening.*—In making the design there are two styles from which to choose; only the skilled artist can combine the two.

**I. Geometrical Style.**

In this method of landscape-gardening the grounds are laid out in squares, circles, or other geometrical designs (Fig. 137). The trees are planted in straight rows, the shrubs trained to regular patterns, and the walks and drives form definite angles.

This style may be followed with pleasing effect along public boulevards, around large buildings (Fig. 137) with steeples and spires, and particularly where the building is a large one upon a small area. It heightens the outline of

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* M. G. Van Rensselaer's *Art Out-of-Doors.*

FIG. 137.—GEOMETRICAL DESIGNS.

the building and emphasizes its importance. Many other places might be mentioned where the formal style of gardening would be effective and desirable. But over large estates, in rural places and suburban homes, where the character of the surrounding landscape retains much of its natural beauty, a formal system would be entirely out of place.

**II. Natural Style.**

This is best liked by Americans for country homes and schools, and is certainly the one best adapted to them. Nature furnishes ample material and many suggestions for the arrangement of it. He who succeeds in preserving the natural charms of a place, its spirit and sentiment, though he does not attain to the highest perfection, is far in advance of the one whose first attempt is to obliterate everything natural in order that he may substitute some stilted and artificial plan.

Though the landscape-artist has given due respect to the natural surroundings, that is not all there is for him to do. It is only a right beginning. He has now the artificial features—walks, drives, fences, etc.—to blend and harmonize in his landscape. These should be as few as convenience will permit. "They should neither be so straight as to lack beauty, nor so meandering as to lack good sense." * There

* M. G. Van Rensselaer's *Art Out of Doors.*

should be a legitimate reason for a curve in a drive. Sometimes there will exist naturally a small hill, a clump of bushes, or a tree that will afford a sufficient reason for turning aside. Otherwise one can make the curve *seem* natural by planting shrubs or a tree. Whatever be the device, it should be something permanent and real; something that could not be easily destroyed or removed. A flower bed would not be a real obstruction ; it would offer no resistance to passing wheels. Not only would it be unsuitable on account of its trivial, transitory nature, but upon grounds large enough to require a road, a flower bed would be entirely out of place in the foreground. The same principle holds true in the construction of paths as in the construction of drives. Paths and drives are for utility, not for beauty; then with that aim they should be made.

A still more difficult problem than that of walks and drives must be met, and that is what to plant and how to plant. This question ought to be studied, for there are few places but what could be improved by the judicious use of ornamental plants. Mrs. Van Rensselaer says: "Two trees and six shrubs, a scrap of lawn, and a dozen plants may form either a beautiful little picture or a huddled disarray" of forms and colors. Too often is found the "huddled disarray" instead of the beautiful picture.

The aim in placing the plantings should be to so arrange them as to allow an uninterrupted sweep to the line of vision wherever some pleasing landscape lies beyond, and to hide from view any buildings or objectionable objects.

The sky-line should neither be too much broken nor too monotonous—perhaps on one side rising high above a mass of trees, with possibly a spire of poplar, while on the other side it sinks to the surface of meadow or lake.

Lawns form the basis of natural grounds for home or school. The center of the grounds in front of the house should generally be devoted to an open, unencumbered, well-kept lawn—a beautiful foundation for any grounds. "These lawns may be kept clipped, or the grass may be allowed to grow at its own sweet will; but clipped lawns have a distinct suggestion of artificiality, and the clipping should be confined to the vicinity of buildings or other positions where smooth surfaces and straight lines are already in evidence (Fig. 137). The unmowed lawn is suitable for larger pieces and for more emphatically natural surroundings"* (Fig. 138).

The plantings should be upon the boundaries, near the building, and in the background. "One would not want the furniture in the parlor to take up three-fourths of the room; much

* Waugh's *Landscape Gardening*.

FIG. 138.—NATURAL STYLE.

less would one want the green carpet of the lawn nearly covered with such furniture as trees and flower beds." * And one might emphatically add much less such monstrosities as trellises, pattern beds, rockeries, camp-kettles, vases, paint-buckets, and sewer-tiles. A summer-house, too, is out of taste upon the front lawn. These would mar the harmony of the whole surroundings.

*The materials* for plantings—trees, vines, shrubs, and flowers—are countless in number and of infinite variety. In the selection and grouping of these, harmony of color, form, and texture must not be forgotten. Yet the element of variety must enter in, or the picture will grow monotonous, however beautiful it may be.

*Trees.*—The most valuable plantings from the standpoint of beauty and utility are the shade-trees. Their artistic value is embodied in the three qualities—form, texture, and color.

The form of a tree is determined by its outline as described against the sky or other trees. It may be eliptical, oval, pear-shaped, or of various other outlines. Structure is another important factor in determining the form of a tree. This relates to the manner of branching, which may vary all the way from the drooping habit of the "weeping" willow to the aspiring branches of the poplar. Thus may be

* Waugh's *Landscape Gardening.*

FIG. 139.—TREES SHOWING KINDS OF TEXTURE.
(Missouri Horticultural Grounds.)

seen the inharmonious effect in massing together trees of these two extremes—as, the willow and the poplar.

The texture of a tree is determined largely by the form and the density of its foliage (Fig. 139). By comparing the leaves of the arbor-vitæ and those of the pine, the great trembling leaves of the cottonwood with those of the weeping willow, the catalpa and cedar, the extreme difference will be at once apparent.

The seasons bring a succession of charming changes to trees. Spring brings only hints of green; summer brings the dense shadows; autumn brings the glorious colors; but it is left for winter, with its dull gray sky, to bring out the true character or the individuality of the tree—its outline, manner of branching, and the color of its bark.

In summer a tree "is shut in of its own leaves and shadow; but when winter, with icy sword-blade, hacks away the last tatter of summer finery, and leaves the tree to stand naked as an Indian warrior, then does it proclaim itself."*

In the natural style of gardening, trees should stand in irregular groups, or as individuals standing alone, as if singled out on account of unusual beauty of form, color, or structure (Figs. 140, 141).

* W. A. Quayle's *In God's Out-of-Doors.*

The American beech makes a fine specimen tree in rich soil. "In autumn there is a harvest sunlight on the beech leaves very fair to see, but, after all, the beech trunk is the tree's treasure."

The elm, ash, catalpa, chestnut, alder, mulberry, walnut, tulip-trees, maples, and oaks by the score surely give ample material for choice of trees to be used in groups or singly.

As street trees, none can excel the American elm. "The elm-tree is always bewitching. In summer, when you can tell this tree as far as you can catch the contour across the fields by the grace of its pose and its rhythmic swaying of branches, as keeping time to music we do not hear; . . . in winter the tree has its winter array. Flung on the snow or seen against the blue sky or gray, it is as graceful as any tree that spreads under the sky."*

The American sycamore, with its striking color and texture of foliage, is one of our first trees. It is grown on the capitol grounds at Washington.

The sugar-maple is also an excellent street tree; in fact, it is beautiful in many places, especially so in its autumn tints.

The linden may also be used to good advantage as a street tree.

"The general effect of an evergreen forest is that of somberness." In the North the use of

* W. A. Quayle's *In God's Out-of-Doors*, p. 52.

FIG. 140.—AMERICAN ELM (*Ulmus americana*).

FIG. 141.—ASH (*Fraxinus viridis*).

a few evergreen trees adds a pleasing variety, especially in winter.

*Shrubs* may be used for a greater number and variety of purposes than any other kind of plants. When properly massed, they form excellent screens to hide unsightly buildings or shut out some view which is less pleasing than another. These masses of shrubbery do double duty, for they not only act as a screen (Fig. 144), but may, with the addition of a few trees, form an excellent background for the whole picture.

As has been already suggested, groups of sturdy-growing shrubs may be used in the curves of walks and drives as substitutes for a more natural obstacle to necessitate the turning aside. These may give new charm to the landscape by concealing some beautiful vista until the curve has been passed, thus adding the elements of surprise and discovery to the delight of the beholder.

Masses of shrubbery may form little secluded nooks or a quiet corner for a rustic seat, where one may steal away with a book, or simply rest in the cool and inviting retreat (Fig. 142), unconsciously feasting the eye upon the beauty of a far-away hill, a waving meadow, or, it may be, upon an old-fashioned flower garden at one's feet.

With the help of vines, irregular groups of low-growing shrubs along the wall or within the

Waugh's *Landscape Gardening.*

FIG. 142.—A COOL AND INVITING RETREAT.

angles serve to unite the buildings with the grounds, and add to the harmony between them.

To take the place of low-growing shrubs along the walls and in the angles of northern exposures, nothing is more beautiful than ferns

FIG. 143.—FERNS AND PHLOX.

with their feathery fronds (Fig. 143), which can be used so effectively in house decorations.

When it becomes necessary to have a fence or a hedge there are many shrubs adapted for this purpose—as, roses, barberries, japonicas, bush honeysuckles, privets, arbor-vitæs, elder bushes, sumachs, and a dozen others. If several kinds of these shrubs are allowed to form a continuous yet irregular band, becoming broader

FIG. 144.—MASS OF SHRUBBERY.

Spirea, snowball, and barberry. Narcissus and lily-of-the-valley in the foreground. (Horticultural Grounds, Missouri Experiment Station.)

in one place and higher in another, and in the background merging into a clump of tall shrubs or small trees, the effect will be much more natural than the closely sheared, stiff hedge.

Where a number of varieties, species, or genera of varying habits are brought together in a group of shrubbery, the effect produced by the shades of differences in form and color and texture is usually more pleasing than that of a group formed from any one kind alone.

For screens and masks, tall-growing, graceful shrubs should be used for the background or the center of the mass, and the outlines should gradually lose themselves in the lower plantings and green sward (Fig. 144). The plantings must be dense enough to conceal the view and to hide all trunks. Neither trees nor shrubs should expose long, bare trunks, making them look as though they were upon stilts. For this reason it is better to plant thickly, and cut out some shrubs when they need thinning.

In massing shrubbery, again the gardner needs to know his plants. He should know those that first put forth their leaves in spring, the time of blooming, and the character of flowers and fruit. In general, mass those shrubs with the darker, restful colors in the background and those of lighter shades in the foreground. Those forms that blossom successively should be selected, for

barberry fruit crop?

it is in this constant change that we have one of the chief charms of the garden.

As to material, the common native shrubs are really the best. Dogwoods (Fig. 145), elders, crab-apples, Judas-trees, sumachs, buckberries, snowberries, wild roses, greenbriers, honeysuckles, currants, spice-bushes, and buttonbushes—all are beautiful, each in its season.

Besides these native plants, there are scores of beautiful and inexpensive ones to be had—as, the lilac, mock-orange, barberry, japonica, snowball, spirea, deutzia, hydrangea, weigelia, and many beautiful varieties of roses.

There are multitudes of hardy climbers and annuals that may be used over porches, arbors, and against the bare masonry of buildings. For example, the climbing rose, honeysuckle, wistaria, Virginia creeper, clematis, trumpet-vine, wild grape, and hop-vine. Such annuals as cypress, Madeira, cinnamon-vine, wild cucumber, morning-glory, and moon-vine may often be used to advantage.

Not all climbers will look well together, nor be suited for all places. Each has a special charm and beauty of its own, determined by its habit of growth, and the character of its flowers and foliage. Hardy climbers are more effective in uniting the lawn and walls of the house than annuals, which are present for a season and then gone, leaving not only the junction of the soil

FIG. 145.—DOGWOOD IN FLOWER.

and walls bare, but the work to be done over again the next year.

*Flowers.*—While lawn, trees, and shrubs are the main features of our plantings, the flowers must not be forgotten. True, many flowers will be had from month to month from the shrubs, if they have been rightly chosen. But some flowers must be grown, not so much for the sake of the picture "as for their own sweet sake."

First, let flowers of the wild-wood be planted. Let violets of all kinds, sweet-williams, bluebells, anemones, spring beauties, or dog's-tooth violets peep out from shady recesses among the grass and shrubbery.

The old-fashioned flowers, such as phlox, poppy, marigold, pink, petunia, verbena, and portulacca, must not be forgotten. These are appropriate for the flower garden proper, but should not be scattered over the lawn to disfigure it.

"I have in mind a garden old,
  Close to a little-known highway,
Where aster, pink, and marigold
  Keep their long summer holiday.
'Mid dreams and visions manifold
I have in mind a garden old.

"The fragrance of old-fashioned flowers,
  Where hollyhocks and daisies blow,
Floats on the wings of summer showers
  Across the fields of long ago.
Lo! from the sweet, rose-ripened bowers,
The fragrance of old-fashioned flowers."

—Frank Walcott Hutt.

Asters, chrysanthemums, pansies (Fig. 146), nasturtiums, and California poppies afford flowers for cutting, but do not grow them in beds outside of the flower garden. Rather let them fill irregular nooks at the edge of the shrubbery,

FIG. 146.—PANSIES.

and shrub and flower will each enhance the beauty of the other (Fig. 144).

Bulbs may be used in much the same manner as other flowers, and the season of blossoms be greatly advanced. The flowers from many bulbs are of surpassing beauty—as, the tulip, jonquil, and the lily-of-the-valley. Two others that are most pleasing when dotted here and there over the lawn are those cheery little harbingers of spring, the crocus and the un-

assuming little snowdrop, the most welcome of all.

*Temporary Screens.*—If screens are needed for a season, what could be more beautiful than

FIG. 148.—SHALL THE CHILDREN PLUCK FLOWERS OR RATTLE TIN CANS IN THE BACK YARD?

the tall sunflowers flanked by bashful golden-rods, with their torches of shining gold? If anything could be more beautiful, it is these same plants, now robed in duller hue, casting

Waugh's *Landscape Gardening.*

FIG. 147.—BACK-YARD SCREEN.

their outlines against the winter sky, and nodding a welcome to the birds who come to partake of their bounties—or blossoming again, this time in snowy whiteness.

Hollyhocks, castor-beans, cosmos, dahlias, chrysanthemums, and asters also make effective

FIG. 149.—A BOUQUET OF SWEET-PEAS.

back-yard screens (Fig. 147), as do also sweet peas, morning-glories, moon-vines, wild cucumbers, and Madeira-vines, if furnished with a support. Here, as in other plantings, one, by rightly choosing from among the myriads of tall-growing plants or vines, may have an abundance of flowers throughout the season. Among annual climbers, sweet peas should be given the preference, since they furnish an abundance of fragrant flowers (Fig. 149) for decorating the

Mina lobata.

rooms and table from June to October, if the flowers are picked regularly and the seed pods not allowed to form. The vines should be given a support as soon as the tendrils appear. Wire netting makes a good and durable support for sweet peas.

*Water.*—If the possibilities of a place include water in the form of rivulet, stream, or pond, the owner is indeed fortunate. Running water enlivens a landscape; still water renders it peaceful and quieting.

Along the wooded banks of the *brook* one expects to find "tangles of vines and branches and brakes."

The pond or small lake, itself a thing of beauty, offers unusual opportunities for the skill of the gardener. Ash and sycamore and willow and alder are looked for along its banks, and it is surely a disappointment if none of them are mirrored in its silvery surface; for the reflections in the water (Fig. 150) are the best part of the picture.*

A pond may simply look like a "cup set in the ground," or form the most beautiful and essential part of the picture. A fringe of willows may overhang its banks here and there. At other points the grass and rushes should quench

* Before leaving the subject, the student should be required to draw an original design for a geometrical style and one for the natural style of landscape-gardening.

Waugh's *Landscape Gardening.*

FIG. 150.—A SMALL LAKE, WITH WELL-SELECTED PLANTINGS

their thirst in the water's brink, while "further along the sedges and cattails may jut far out into the still water," upon the surface of which quietly rests the lily pads (Fig. 150).

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Valuable literature upon agricultural subjects may be obtained free or at a comparatively low cost, directions for securing which are given below:

## PUBLICATIONS OF THE UNITED STATES EDEPARTMENT OF AGRICULTURE.

1. Year-books. *Very valuable.* For general distribution. Apply through Congressman of your district.
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3. Monthly list of publications and "Experiment Station Record." Address Director of Agricultural Experiment Stations, Washington, D. C.

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1. Bulletins issued by one's own State Experiment Station. Address Director of Agricultural Experiment Station, and have your address put on mailing list of your own State for publications.
2. Many valuable bulletins may often be obtained from other State Experiment Stations by asking the Director of the States for them.
3. On the following page is a list of State Experiment Stations in the United States, taken from "Experiment Station Record" of 1902.

# AGRICULTURAL EXPERIMENT STATIONS.

Alabama—College Station: *Auburn.* Canebrake Station: *Uniontown.* Tuskegee Station: *Tuskegee.*

Alaska—*Sitka.*

Arizona—*Tucson.*

Arkansas—*Fayetteville.*

California—*Berkeley.*

Colorado—*Fort Collins.*

Connecticut—State Station: *New Haven.* Storrs Station: *Storrs.*

Delaware—*Newark.*

Florida—*Lake City.*

Georgia—*Experiment.*

Hawaii—Federal Station: *Honolulu.* Sugar Planters' Station: *Honolulu.*

Idaho—*Moscow.*

Illinois—*Urbana.*

Indiana—*Lafayette.*

Iowa—*Ames.*

Kansa—*Manhattan.*

Kentucky—*Lexington.*

Louisiana—State Station: *Baton Rouge.* Sugar Station: *Audubon Park.* North Louisiana Station: *Calhoun.*

Maine—*Orono.*

Maryland—*College Park.*

Massachusetts—*Amherst.*

Michigan—*Agricultural College.*

Minnesota—*St. Anthony Park, St. Paul.*

Mississippi—*Agricultural College.*

Missouri—College Station: *Columbia.* Fruit Station: *Mountain Grove.*

Montana—*Bozeman.*

Nebraska—*Lincoln.*

Nevada—*Reno.*

New Jersey—*New Brunswick.*

New Hampshire—*Durham.*

New Mexico—*Mesilla Park.*
New York—State Station: *Geneva.* Cornell Station: *Ithaca.*
North Dakota—*Agricultural College.*
North Carolina—*Raleigh.*
Ohio—*Wooster.*
Oklahoma—*Stillwater.*
Oregon—*Corvallis.*
Pennsylvania—*State College.*
Porto Rico—*Rio Piedras.*
Rhode Island—*Kingston.*
South Carolina—*Clemson College.*
South Dakota—*Brookings.*
Tennessee—*Knoxville.*
Texas—*College Station.*
Utah—*Logan.*
Vermont—*Burlington.*
Virginia—*Blacksburg.*
Washington—*Pullman.*
West Virginia—*Morgantown.*
Wisconsin—*Madison.*
Wyoming—*Laramie.*

# PUBLISHING HOUSES.

Address of publishing houses whose books have been mentioned in the reference lists at the end of the various chapters.

The number in the reference list corresponds to the number given to the publishing house :

(1) D. Appleton & Co., New York.
(2) Comstock Publishing Co., Ithaca, N. Y.
(3) G. P. Putnam's Sons, New York.
(4) Orange Judd Co., New York.
(5) J. B. Lippincott Co., Philadelphia.
(6) A. Flanagan, Publisher, Chicago.
(7) Henry Holt & Co., Boston.
(8) The American Book Co., Chicago.
(9) A. L. Burt, New York.
(10) The Macmillan Co., New York.

# GLOSSARY.

**Ab-ra′sion.** The act of wearing or rubbing off.

**Ad-he′sion.** The attraction between unlike or distinct particles of matter.

**Ad′ven-ti′tious.** Out of the usual place.

**Al-bu′mi-noids.** Organic compounds containing nitrogen.

**At-a-vist-ic.** The liability of any characteristic of any ancestor to recur in subsequent generations.

**A-tom′ic.** Pertaining to atoms, the ultimate indivisible particles of matter.

**A-vail′able food.** Food which is in such a condition that the plant can and will use it.

**Bal′anced ra′tion.** Food consisting of such proportions of various elements that the least possible amount will be wasted.

**Bud′ding-stick.** A shoot of one season's growth.

**Cal-ca′re-ous.** Composed of, or containing lime.

**Cam′bi-um.** The ring of thin-walled formative tissue between the bark and wood in which growth takes place.

**Car-bo-hy′drate.** Foods containing carbon but no nitrogen; they also contain oxygen and hydrogen in the same proportion as they are found in water.

**Cer′ci** (pl. of **cer′cus**). The jointed antenniform appendages of the posterior somites of certain insects.

**Chem′ic-al af′fin′i-ty.** Attraction which acts at insensible distances between atoms of unlike elements, forming compounds.

**Chlo′ro-phyll.** Green granular matter formed by the leaves and green stems of plants.

**Chrys′a-lis.** Quiescent state of butterflies and moths from which the adult insect comes forth.

**Co-he′sion.** Attraction between like particles.

**Com′post.** Fertilizing mixture; stable compost means barn-yard manure.

**Cor-rod′ing.** Eating away by degrees.

**Dis-sem-i-na′tion.** Scattering.

**Dor′mant.** Inactive, quiescent.

**Dis-in′te-gra′tion.** Crumbling to fragments.

**E-mul′si-fy.** To reduce an oily substance to a milky fluid, in which the fat globules are in a very finely divided state.

**En′to-mol′o-gy.** The science which deals with the life history and description of insects.

**Er-ro′ne-ous-ly.** By mistake; not rightly.

**Ex′cre-ment.** That which is discharged from the animal body as useless. **Ex-cre′ta.**

**Fil′ter-pa-per.** A porous unsized paper that retains the sediment when liquids are passed through it.

**Fun′gi-cide.** A preparation which kills fungi.

**Fun′gus** (pl. **fun′gi**). A flowerless plant lacking chlorophyll (green coloring-matter).

**Green ma-nur′ing.** Vegetation plowed under for fertilizing purposes.

**Hu′mic.** Pertaining to or derived from vegetable mold.

**Hu′mous,** *adj.* Containing humus.

**Humus,** *n.* Decayed vegetable or animal matter.

**Hy-dra′tion.** Combining with water to form a hydrate, which is usually a neutral salt. Slaked lime is a hydrate.

**In-oc′u-late.** To communicate bacteria germs by introducing matter infected by them.

**In-sec′ti-cide.** A preparation to kill insects.

**La′bel.** To apply a label to, to mark with a name, etc.

**Li′chen.** Algæ and fungi leading a life in partnership.

**Marl.** A mixed earthy substance consisting of carbonate of lime, clay, and siliceous sand in variable proportions.

**Me′di-an.** An ideal line dividing the body of an animal longitudinally and symmetrically into right and left halves.

**Mi′cro-or-gan-ism.** Microscopic organism, here meaning bacteria.

**Mo-lec′u-lar force.** Attraction between molecules.

**Muck.** Decayed vegetable matter.

**Nod′ule.** Small rounded masses, knots, or prominences formed on roots of leguminous plants by infesting bacteria.

**Note.** Used in connection with exercises and experiments, means observe and record your observation.

**Nox′ious.** Injurious; destructive.

**Ox′i-da′tion.** Combining with oxygen to form an oxide.

**Par′a-sit′ic.** Living upon or in, or deriving its nourishment from some other living being.

**Plu′mule.** The bud, or first shoot above the cotyledons, of a young plantlet.

**Pol′lin-a′tion.** Conveying pollen from stamens to pistil.

**Pre-cip′i-tate.** A substance which, having been dissolved, is again separated from the solution, and falls to the bottom of the vessel.

**Pre-da′ceous.** Preying upon or devouring other insects.

**Pu-bes′cent.** Covered with very fine, short hairs.

**Pu-pat-ing.** Going into the pupa or inactive (usually) stage, from which the adult insect emerges.

**Rad′i-cle.** The stem part of the embryo; the lower part, which forms the root-system.

**Raf′fia.** A commercial product formed from several species of the genus Rapphia. A strong fiber used for tying in nursery work.

**Res′i-due.** That which remains after a part is taken; remainder; dregs.

**Sci′on.** A shcot of one season's growth used in bud propagation.

**Seg′ment.** One of the parts into which any body naturally separates or is divided.

**Sil′age.** Green food preserved in a silo.

**Si-li′ceous.** Containing silica.

**Soil′ing.** The system of feeding farm animals in a barn or enclosure with fresh grass or green fodders—as, corn, rye, and oats.

**Spore.** One of the minute grains in flowerless plants which performs the function of seed.

**Ster′il-ize.** To make unproductive; to destroy all spores or germs so as to prevent the development of bacteria.

**Stock.** A seedling tree used in bud propagation.

**Strat′i-fied.** Divided into layers or strata.

**U-ni-cel′lu-lar.** Consisting of but one cell.

**Vol′a-til-ize.** To pass off in vapor.

**Vol′u-ble.** Twining.

# INDEX.

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